SEL

TECHNICAL MANUAL
FOR
DIGITAL CARRIER ANALYSIS TEST SET
MODEL 273A

Bowmar

WHEN QUALITY COUNTS

Communications Test Equipment

Bowmar/ALI Inc.
531 Main Street
Acton, Mass. 01720

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FOR
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MODEL 273A

MANUFACTURED BY:

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MODEL 273A
DIGITAL CARRIER ANALYSIS
TEST SET

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1.0 INTRODUCTION

1.1 Description

The Bowmar/ALI Model 273A Digital Carrier Analysis Test Set is a portable instrument capable of performing a reliable check of T1 (DS-1) 1.544 Mb/s, and T1C (DS-1C) 3.152 Mb/S, PCM communications systems. Special features include testing of Automatic Protection Switches (APS), both hysteresis and 51A types; DDS two hour performance tests; and with Option -1, bridge or terminate on line lengths between 0 - 4000 feet as provided by an Automatic Line Build Out (ALBO) receiver.

The 273A transmitter provides four T1 compatible outputs with a 1,048,575 bit quasi-random sequence identical to that provided by Bell System's J98710R T1 quasi-random signal source (QRSS). At the T1C rate the sequence is modified to permit consecutive zero strings of of up to nineteen "0's". A strap option is provided which will restrict consecutive zeros to fourteen, if desired. The QRSS provides a realistic degree of stress at both the T1 and T1C data rates for the facility under test.

The receiver portion of the instrument operates independently of the transmitter. It performs both bipolar-violation-detection on any signal and bit-error-detection while working in conjunction with its own transmitter or equivalent source. The 273A can, therefore, test any system or system component which removes bipolar violations and/ or causes logical errors without causing violations.

Fully solid state, this instrument also has such features as self-test, three digit display with overflow indicator, automatic and manual resynchronization of receiver, error insertion at the transmitter for circuit identification, receiver status indicators, comprehensive count interval including timed setting, and selectable line bridge or terminate.

1.2 Scope

This manual contains descriptive details of the Error Rate Test Set plus related applications notes, maintenance information, diagrams, and parts information. The descriptive details are reduced to categories of physical and functional specifications, operating procedures, and operating principles. The manual's purpose is to provide sufficient familiarization to enable effective use and proper maintenance of the Test Set.

1.3 Specification Summary

Output Pattern:	T1 A 1,048,575 bit quasi-random pattern limited to 14 consecutive zeros; compatible with Western Electric J98710R Quasi-Random Signal Source.

T1C A 1,048,575 bit quasi-random pattern with 19 consecutive zero components. A strap option is provided to limit consecutive zeros to 14 (APS/BUF MODULE).

Input: Balanced; one jack which accepts a WE310-Type plug (T & R) and one mini 310 (T & R)

Outputs: Four balanced outputs distributed by four WE310-Type and two mini 310 jacks (T & R)

Auxiliary Outputs: Three BNC connectors
1. ERRORS (Unbalanced)
2. BLOCK ERRORS (Unbalanced)
3. EXTERNAL CLOCK IN (Balanced)

One GND (Ground) terminal and four pin jacks which allow monitoring of the following internal signals (Unbalanced):
1. TRANSMITTER BIT SYNC.
2. TRANSMITTER WORD SYNC.
3. RECEIVER BIT SYNC.
4. RECEIVER WORD SYNC.

Controls:

MODE Switch — 3-position:
1. VIOLATIONS
2. APS
3. ERRORS

BIT RATE Switch — 2-position:
1. T1 1.544 mHz
2. T1C 3.152 mHz

SYNC. — 2-position:
1. AUTO
2. MANUAL

SELF TEST Switch: — 3-position:
1. INTERUPT DATA (momentary)
2. NORMAL
3. INSERT ERRORS (momentary)

APS TEST Switches:

A. RANGE: 5-position:
1. 10^{-3}
2. 10^{-4}
3. 10^{-5}
4. 10^{-6}
5. 10^{-7}

	B. SEQUENCE: 5-position 1. START 2. NO TR (No Transfer) 3. TR 4. NO RST (No Restore) 5. RST
POWER Switch	2-position: 1. ON 2. OFF
RESET/RESYNC. Switch	Momentary Toggle
TIMER STATUS Switch	Momentary Toggle
DISPLAY FORMAT:	4-position: 1. INDIVIDUAL 2. ERROR-SEC (Seconds) 3. ERROR - DECISEC (0.1 Seconds) 4. 0.3 MS BLANK
DISPLAY INTERVAL (SEC) Control:	1 to 10 seconds, plus a detent setting for HOLD.
COUNT INTERVAL (BITS) Switch:	6-position: 1. 10^6 2. 10^7 3. 10^8 4. 10^9 5. CONT (Continuous) 6. TIMED
TIMER (MIN) Switches:	RANGE: 1 - 999 minutes 1. MINUTES X 10^2 2. MINUTES X 10^1 3. MINUTES X 10^0
INPUT TERMINATION Switch:	2-position: 1. TERM (Terminated 100 ohms) 2. BRIDGE ($>$ 1000 ohms)
Indicators:	
RECEIVE STATUS Indicators:	6 separate indicators: solid state: 1. NO DATA 2. LOST DATA 3. NO SYNC 4. LOST SYNC 5. LOST POWER 6. ALL 1's

DISPLAY STATUS Indicators:	2 separate indicators; solid state 1. OVERFLOW 2. COUNT
DISPLAY:	3-digit; solid state.
FUSE and SPARES:	AC POWER: 1 each 3AG, 1/2A, Slow Blow DC POWER: 1 each 3AG, 3/4A, Slow Blow Spare fuses located in cover.
POWER SOURCE:	115 VAC ± 15% 47 to 63 Hz, Single Phase or 48 VDC ± 4 VDC positive ground to sleeve, negative 48 to Tip. WE 410 Type plug.
Receiver Input Threshold:	0.2 to 6.0 peak; automatic threshold control for operation at MONITOR jack, cross-connect bay or up to 750 feet from source.
Option -1	0 to 4000 ft. cable length driven by a 3 V peak bipolar source.
Sync. Acquisition Time:	Less than 200 clock pulses. (Test Set will not resync on isolated error bursts of less than 6 consecutive errors).
Printer Interface Option P	Fifty pin mini blue ribbon connector format; Three parallel BCD digits with print and test set control commands.
Transmitter Output T1 Bipolar Pusle Characteristics	
Height of output pulse:	3 V ± 0.3 V
Unbalance in height of negative and positive pulse:	0.15 V
Width of output pulse (half amplitude)	324 ± 30 nsec
Unbalance in width of negative and positive pulse:	± 15 nsec
Maximum rise or fall time:	80 nsec
Overshoot at trailing edge of pulse:	10 to 30% of pulse height with decay of 10% or less of base line-to-peak value within 400 nsec.

Transmitter Output T1C Bipolar Pulse Characteristics	
Height of Output Pulse:	3 V ± 0.3 V
Unbalance in Height of Negative and Positive Pulse:	0.15 V
Overshoot	Less than 10% of Pulse Height
Width of Output Pulse (Half Amplitude)	160 nsec ± 15 nsec
Unbalance in Width of Negative and Positive Pulse:	± 15 nsec
Maximum Rise or Fall Time:	40 nsec
Operating Environment:	0 to 50°C (32 to 120°F) to 95% relative humidity.

2.0 INSTALLATION AND SELF TEST

2.1 Preparation

2.1.1 Remove the Digital Carrier Analysis Test Set from its shipping container.

2.1.2 Remove the front cover.

2.1.3 Check for the presence of 3AG, 1/2A, (Front Panel) and 3AG, 3/4A (Rear Panel) slow blow fuses.

2.1.4 Remove the power cord from the front cover and connect the Test Set to a 115 V ac, 50-60 Hz, single-phase power source.

2.1.5 Set the POWER switch to ON and note whether or not the indicator illuminates.

2.2 Check/Self Test Procedure

Follow the procedure outlined below.

2.2.1 Set switches to the following initial positions:

MODE	-to VIOLATIONS
DISPLAY FORMAT	-to INDIVIDUAL
BIT RATE	-to T1
SYNC MODE	-to MANUAL
SELF TEST	-to NORMAL
DISPLAY INTERVAL (SEC)	-to '1' (full counterclockwise)
COUNT INTERVAL (BITS)	-to '10^6'
RESET/RESYNC	-to Momentarily Actuate and Release

2.2.2 Observe indicators for the following initial responses:

NO DATA	-OFF
LOST DATA	-OFF
NO SYNC	-ON
LOST SYNC	-ON
LOST POWER	-OFF
All 1's	-OFF
OVERFLOW	-OFF
COUNT	-alternately on for approximately 2/3 second, off for approximately 1 second.
DISPLAY	-'0' (constant)

2.2.3 Turn the DISPLAY INTERVAL (SEC) control clockwise to the '10' position. The COUNT indicator should alternately be ON for approximately 2/3 second and OFF for approximately 10 seconds.

2.2.4 Place the DISPLAY INTERVAL (SEC) control in its HOLD (detent) position and momentarily operate the RESET/RESYNC switch. The COUNT indicator should come ON for approximately 2/3 second and then remain OFF. indefinitely. Check the off condition for at least twenty seconds.

2.2.5 Place the DISPLAY INTERVAL (SEC) control at some point between '1' and '5'. Hold the SELF TEST switch at its INSERT ERRORS position. The count on the Display should change by increments of two from a starting count of '0' to a final count of '8' while the COUNT indicator is ON. At the count of '8', the Display should hold for the period set by the DISPALY INTERVAL (SEC) control, then it should clear to '0' and begin a new cycle. The first count interval may not yield a total of eight errors, but each succeeding interval should register a count of '8' on the Display.

2.2.6 Holding the SELF TEST switch at its INSERT ERRORS position, change the COUNT INTERVAL (BITS) switch from 10^6 to 10^7. The count on the Display should perform as it did in Step 5 above, however, a full count interval should now register '80'.

2.2.7 Holding the SELF TEST switch at its INSERT ERRORS position, change the COUNT INTERVAL (BITS) switch from 10^7 to 10^8. The count on the Display should perform as it did in Steps 5 and 6 above, however, a full count interval should now register '800'.

2.2.8 Holding the SELF TEST switch at its INSERT ERRORS position, change the COUNT INTERVAL (BITS) switch from 10^8 to 10^9. The count will stop after approximately 11 minutes and 21 seconds. The Display should cycle through a complete count of 0 to 1000, a total of eight times. Since the Display contains only three digits, a count of 1000 will register as '0' with an OVERFLOW indication. The OVERFLOW indicator should come ON at the first count of 1000. It will remain on after this point through the remaining seven cycles of 0 to 1000.

2.2.9 Holding the SELF TEST switch at its INSERT ERRORS position, change the COUNT INTERVAL (BITS) switch from 10^9 to CONT position and momentarily operate the RESET/RESYNC switch. The count on the Display should accumulate as in the preceding steps, and the OVERFLOW indicator should come ON as the Display goes from '998' to '0' and stay ON. Check that count continues for at least 12 minutes after OVERFLOW indicator comes ON.

2.2.10 While holding the SELF TEST switch at its INSERT ERRORS position, momentarily operate the RESET/RESYNC switch. As it is operated the Display should clear to '0', and the OVERFLOW and COUNT indicators should go OFF; the COUNT indicator should come ON again within 2/3 second of Switch release.

2.2.11 Change the COUNT INTERVAL switch from CONT to TIMED. Hold both the RESET/RESYNC and TIMER STATUS switches in their momentary position. Rotate each of the three thumbwheel switches through their ten positions noting a correlation between the DISPLAY and SWITCH position.

2.2.12 Set the TIMER switch to 001 and momentarily operate the RESET/RESYNC switch. The COUNT INDICATOR should stay on for a period of one minute. The Display should read'0' when the TIMER STATUS switch is operated after the COUNT indicator's transition to the OFF state.

2.2.13 Release the SELF TEST switch and return the COUNT INTERVAL (BITS) switch to its 10^6 position.

2.2.14 Set the MODE switch at LOGIC and momentarily operate the RESET/RESYNC switch. The Display indication should be '0' and all RECEIVE STATUS indicators should be OFF.

2.2.15 Push and hold the SELF TEST switch to INTERRUPT DATA. The NO DATA and NO SYNC indicators should come ON. The LOST DATA and LOST SYNC indicators should remain OFF.

2.2.16 Release the SELF TEST switch. The NO DATA indicator should go OFF. The LOST DATA and NO SYNC indicators should be ON. The LOST SYNC indicator should be OFF. The Display should show '888' with an OVERFLOW indication during the COUNT INVERVAL, and any number with OVERFLOW at the end of the COUNT INTERVAL.

2.2.17 Place the SYNC switch to the AUTO position. The NO SYNC indicator should go OFF and the LOST SYNC indicator should come ON. The LOST DATA indicator should remain ON. The Display should register '0' without OVERFLOW.

2.2.18 Momentarily operate the RESET/RESYNC switch. The LOST SYNC and LOST DATA indicator should go OFF.

2.2.19 Push and hold the SELF TEST switch at INSERT ERRORS. The Display should change by increments of two to a final count of '8'.

2.2.20 Change the COUNT INTERVAL BITS switch to the TIMED position. Set the TIMER switches to one minute ('1'). Set the DISPLAY FORMAT switch to the ERROR-SEC position.

2.2.21 Hold the SELF TEST switch in the INSERT ERRORS position and momentarily operate the RESET/RESYNC switch. The COUNT indicator should come ON for a period of one minute. After the count interval is complete, the Display should register between '59' and '61'.

2.2.22 Change the COUNT INTERVAL bits switch to 10^7 and the DISPLAY FORMAT switch to ERROR-DECISEC.

2.2.23 Hold the SELF TEST switch in the INSERT ERRORS position. The Display should count by increments of one to a final count of '40'.

2.2.24 Change the DISPLAY FORMAT switch to 0.3 ms BLANK.

2.2.25 Hold the SELF TEST switch in the INSERT ERRORS position. The Display should count by increments of one to the final count of '40'.

2.2.26 Change the BIT RATE switch to T1C and DISPLAY FORMAT switch to INDIVIDUAL.

2.2.27 Momentarily operate the RESET/RESYNC switch. All RECEIVER STATUS indicators should be OFF and the Display should register '0' without OVERFLOW.

2.2.28 Hold the SELF TEST switch in the INSERT ERRORS position and momentarily operate the RESET/RESYNC switch. The Display should count in increments of two for a final count of '80'.

2.2.29 Return the BIT RATE switch to the T1 position.

2.2.30 Determination of the operational readiness of the Test Set when operating in the APS TEST mode requires the use of an external bipolar signal source and bipolar violations detector. The Bowmar Model 271A (KS-20775 L1), 271B, or 271C (KS-20775 L2) Error Rate Test Set or another 273 may be used to fulfill this requirement. A Bowmar Model 271C will be used for the purpose of outlining a general test procedure.

Using patch cords with WE 310-type plugs at each end, connect a DS1 OUTPUT of the 271C to the DS1 INPUT of the 273 under test; connect any DS1 OUTPUT of the instrument under test to the DS1 INPUT of the 271C.

Set the MODE switch on the 271C to the VIOLATIONS position, COUNT INTERVAL BITS switch to 10^6 and BLOCK ERROR switch to OUT. Momentarily operate the RESET/RESYNC switch. The NO SYNC and LOST SYNC indicators should be ON.

Set the MODE switch on the 273 to APS, and momentarily operate the RESET/RESYNC switch. The Display should be blanked with the NO SYNC and LOST SYNC indicators ON.

The Table below lists a set of APS switch combinations which will completely test this function. Each APS switch combination is followed by a COUNT INTERVAL switch setting and display response pertaining to the testing instrument (271C). Complete each step of the Table, observing that each result complies with the Table's requirement.

INSTRUMENT UNDER TEST				TESTING INSTRUMENT (271C)			
STEP	APS TEST SETTINGS			COUNT INTERVAL BITS SW	DISPLAY		
	SEQUENCE SWITCH	RANGE SWITCH	STD/51A SWITCH		MIN.	NOM.	MAX.
1.	START	$X10^{-3}$	STD	10^6	0	0	0
2.	NO TR	$X10^{-3}$	STD	10^6	500	520	550
3.	NO TR	$X10^{-4}$	STD	10^6	50	52	55
4.	NO TR	$X10^{-5}$	STD	10^7	50	52	55
5.	NO TR	$X10^{-6}$	STD	10^8	30	33	36
6.	NO TR	$X10^{-7}$	STD	10^9	50	52	55
7.	TR	$X10^{-4}$	STD	10^6	200	210	220
8.	NO RST	$X10^{-4}$	STD	10^6	50	52	55
9.	RST	$X10^{-4}$	STD	10^7	30	33	36
10.	START	$X10^{-4}$	51A	10^6	0	0	0
11.	NO TR	$X10^{-4}$	51A	10^6	50	52	55
12.	TR	$X10^{-4}$	51A	10^6	200	210	220
13.	NO RST	$X10^{-4}$	51A	10^6	125	130	135
14.	RST	$X10^{-4}$	51A	10^6	50	52	55

3.0 OPERATION AND APPLICATIONS

3.1 Controls, Indicators, and Connectors

3.1.1 DS1/DS1C INPUT: Two, paralled connected jacks one of which accepts a WE 310-type plug and the other a mini 310 plug. Insertion of a plug into either of these jacks interrupts the Test Set internal loop back and passes data from the system under test to the 273's receiver. Only one input jack at a time should be used.

3.1.2 DS1/DS1C OUTPUT: Six jacks, four of which accept WE 310-type plugs and two accepting mini 310 plugs. The four WE 310-type jacks provide four mutually independant outputs. Each of the mini 310 jacks is wired in parallel with an adjacent WE-310 jack. Only one jack should be connected to an adjacent pair at one time to preserve output impedance and independance. The output impedance of all six jacks is 100 ohm $\pm$ 5%.

3.1.3 BRIDGE/TERM: A two position toggle switch which determines the terminating impedance of the DS1/DS1C input. In the BRIDGE position the input impedance is greater than 1000 ohms while in the TERM position the input is 100 ohms $\pm$ 5%.

3.1.4 AUXILIARY OUTPUTS: four pin jacks and three BNC connectors which monitor the signals listed below; a ground post (GND) is provided for test equipment.

(a) TRANSMITTER BIT SYNC: a 1.544 MHZ, T1, clock signal or 3.152 MHZ, T1C clock signal; square wave.

(b) TRANSMITTER WORD SYNC: a pulse, 324 nsec (160 nsec, T1C) long, generated once per full cycle of the Transmitter sequence generator; changes this output's level from high to ground only for its duration.

(c) RECEIVER BIT SYNC: the clock signal as taken from incoming data by the Receiver clock extractor circuit.

(d) RECEIVER WORD SYNC: a pulse, 324 nsec (160 nsec, T1C) long, generated once per full cycle of the Receiver sequence generator; changes this output level from high to ground only for its duration.

(e) ERRORS: a pulse, 324 nsec (160 nsec, T1C) long, for every error detected by the Receiver, changes this output level from high to ground only for its duration.

(f) BLOCK ERRORS: a pulse, 324 nsec (160 nsec, T1C) long, for every error detected by the Receiver and processed in accordance with the error format selected by the DISPLAY FORMAT switch. The output transition is from high to ground only for its duration.

(g) EXTERNAL CLOCK: This input accepts a 3 ± 1 Volt all 1's bipolar signal. When connected, this signal automatically becomes the Transmitters reference clock which permits the 273 to operate synchronously with the T-Carrier equipment under test.

3.1.5 DISPLAY FORMAT: A four position switch which selects the type of error which will be registered on the Display. Formated errors other than INDIVIDUAL are useful when error bursts are a prevalent line condition.

(a) INDIVIDUAL: Every error detected by the Receiver is counted and registered on the Display.

(b) ERROR-SEC: The data stream is divided into consecutive one second blocks. One or more errors detected in a block are counted as a single error. Error free blocks are not counted.

(c) ERROR-DECISEC: The data stream is divided into consecutive 0.1 SEC blocks. Errors are counted as described for ERROR-SEC.

(d) 0.3 MS BLOCK: The Display counter is blanked for a period of 0.3 MS after an error is detected. The first error is added to the displayed count while errors following within the next 0.3 MS are ignored.

3.1.6 MODE Switch: A 3-position toggle switch used as follows:

(a) VIOLATIONS (up position) or LOGIC (down position): Sets the Test Set for bipolar violations or logical errors; the Transmitter is set for the type of errors it must insert in the quasi-random test sequence, and the Receiver is set for the type of errors it must detect and count.

(b) APS (center position): connects the output of the Receiver section to the input of the Transmitter section; violations are inserted into the Receiver data pattern at a rate selected by the APS TEST, RANGE and SEQUENCE switches.

3.1.7 BIT RATE: A two position siwtch that selects either a T1 (1.544 M bits/sec) or T1C (3.152 M bits/sec) T-Carrier Bit Rate and DS1/DS1C format respectively.

3.1.8 SYNC MODE switch: a 2-position toggle switch used as follows:

(a) AUTO (up position): sets the Test Set for automatic resynchronization in the event that synchronization is lost.

(b) MANUAL (down position): Synchronization may be regained by operating the RESET/RESYNC switch.

NOTE: The LOST SYNCHRONIZATION THRESHOLD is factory set for an error rate of twelve errors within fourty bits. Two other thresholds may be selected: 120 errors in 400 bits and 1200 errors in 4000 bits. Strap options for these thresholds are located on the RECEIVER LOGIC BOARD. Connecting straps across terminal pairs A1 and B1 selects the 120 bit error in 400 bit threshold. Connecting straps across pairs A1, B1, A2 and B2 selects the 1200 error in 4000 bit threshold.

3.1.9 SELF TEST switch: a 3-position momentary toggle switch used as follows:

(a) NORMAL (center position): for normal operation of the Test Set. With no connection to the DS1/DS1C INPUT (Receiver), the Receiver and Transmitter are directly linked. At the same time if the MODE switch is set for LOGIC, all indicators will be off and the Display will show no count; if the MODE switch is set for VIOLATIONS, the NO SYNC and LOST SYNC indicators will be held on. The Test Set will not attempt to synchronize when operated in the VIOLATIONS or APS modes.

(b) INTERRUPT DATA (momentary up position): opens the link between Receiver and Transmitter, causing both the NO DATA and NO SYNC indicators to come on. Return to NORMAL position forces the NO DATA indicator off and LOST DATA ON. If the SYNC MODE switch is at AUTO, the LOST SYNC indicator will replace the NO SYNC upon return to NORMAL. This function is disabled when a plug is inserted into the DS1/DS1C INPUT jack.

(c) INSERT ERRORS (momentary down position): inserts either logical errors or bipolar violations (depending on the MODE switch setting) into the Transmitter test sequence. These errors appear at the DS1/DS1C OUTPUT (Transmitter) jacks and are directed to the Receiver input via internal loop back wiring. In the Receiver, these errors exercise detection and counter circuitry and are registered on the Display. Since a known quantity of errors is injected into the Receiver, this process provides a quick self-test.

The INSERT ERRORS position is also useful for line identification when the 273 is connected to T-Carrier equipment. When used in this fashion, all MODE switch positions will insert eight errors (violation errors in APS or VIOLATIONS mode, data errors in LOGIC mode) in 10^6 bits into the transmitted DS1/DS1C output. In the APS position the RANGE and SEQUENCE switches are disabled when the INSERT ERRORS switch is activated.

Note: The SELF TEST switch does not permit observation of the violation rates selected when the MODE switch is set to the APS position. An externally connected bipolar signal source and violation detector are required to determine proper operation. (Reference par. 2.2.30.)

3.1.10 DISPLAY INTERVAL (SEC) control: a variable potentiometer which determines the period of time the display will hold any given count; covers a range of from 1 to 10 seconds or continuous (HOLD).

3.1.11 RESET/RESYNC switch: a free-return toggle switch that resets the Display counter, initiates a new count interval, resets the LOST SYNC indicator in LOGIC mode, resets the LOST DATA indicator and initiates resynchronization.

3.1.12 COUNT INTERVAL (Bits): a 6-position switch whose settings determine the period of time that the counter circuits will count errors. Bit time intervals are selected by the 10^6, 10^7, 10^8, 10^9, switch positions. The time base for these intervals is generated from the WORD SYNC signal. Therefore, the 10^6 bit position actually relates to 1,048,575 bits or approximately 10^6 (1,000,000 bits). Subsequent positions (10^7, 10^8, 10^9) are 10's multiples of 1,048,575.

(a) CONT: In this position the count will continue to tally until reset by the RESET/RESYNC switch.

(b) TIMED: The count period is determined by the setting of the 3 timer thumbwheel switches in minutes.

3.1.13 TIMER: Three, ten position, thumbwheel switches which set a count interval between 0 and 999 minutes in one minute steps. A TIMER cycle is initiated with the momentary operation of the RESET/RESYNC switch. At the end of the TIMER cycle the final number registered on the Display is maintained regardless of the position of the DISPLAY INTERVAL control.

3.1.14 TIMER STATUS: a 2-position free return toggle switch which when held in the down position permits viewing on the Display of the time remaining in a TIMER cycle in minutes.

3.1.15 APS TEST switches: a 5-position rotary switch (SEQUENCE) and a 5-position rotary switch (RANGE) control the insertion of bipolar violations when operating in the APS mode. The 2-position toggle switch (STD/51A) further modifies the inserted violation rate to effectively test 51A Span Line equipment.

Violations uniformly spaced in time are inserted at the error rates listed in the table below:

SEQUENCE SWITCH	STD/51A SWTICH	BPV RATE RANGE SWITCH 10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
START	STD	0	0	0	0	0
NO TRANSFER	STD	$10^{-3.3}$	$10^{-4.3}$	$10^{-5.3}$	$10^{-6.5}$	$10^{-7.3}$
TRANSFER	STD	$10^{-2.7}$	$10^{-3.7}$	$10^{-4.7}$	$10^{-5.9}$	$10^{-6.7}$
NO RESTORE	STD	$10^{-3.3}$	$10^{-4.3}$	$10^{-5.3}$	$10^{-6.5}$	$10^{-7.3}$
RESTORE	STD	$10^{-4.5}$	$10^{-5.5}$	$10^{-6.5}$	$10^{-7.7}$	$10^{-8.5}$
START	51A	N/A	0	0	0	0
NO TRANSFER	51A	N/A	$10^{-4.3}$	$10^{-5.3}$	$10^{-6.3}$	$10^{-7.3}$
TRANSFER	51A	N/A	$10^{-3.7}$	$10^{-4.7}$	$10^{-5.7}$	$10^{-6.7}$
NO RESTORE	51A	N/A	$10^{-3.9}$	$10^{-4.9}$	$10^{-5.9}$	$10^{-6.9}$
RESTORE	51A	N/A	$10^{-4.3}$	$10^{-5.3}$	$10^{-6.3}$	$10^{-7.3}$

TABLE 3-1

Note: To avoid confusion to the operator, these rates are available only when the MODE switch is set to APS. However, some operators may find these rates useful when testing in the VIOLATIONS or LOGIC mode. It is possible to override this lock out feature by adding a strap to the terminal pair designated 'A' located on the BUFFER/APS module (A7). Care should be taken to maintain the SEQUENCE switch in the START position when error (Logic/Violations) insertion is not desired, if this strap option is selected.

3.1.16 DISPLAY: A 3-digit, seven segment, solid state indicator which presents a numerical readout of error count accumulated during any count interval.

3.1.17 OVERFLOW Indicator: A solid state indicator which is energized when the error count exceeds the numerical capacity of the Display (1000).

3.1.18 COUNT Indicator: A solid state indicator which is energized during error count intervals.

3.1.19 RECEIVE STATUS Indicators: Six solid state indicators for the following purposes:

(a) NO DATA: is energized when data is not being presented to the receiver.

(b) LOST DATA: is energized after data has been lost and subsequently regained; remains on until the RESET/RESYNC switch is activated. This indicator, with the NO DATA indicator, thus provides coverage of data loss from the instant of stoppage to the instant of manual resynchronication.

(c) NO SYNC: is energized when the receiver is not synchronized to incoming data, or when the test set is in the VIOLATIONS or APS mode.

(d) LOST SYNC: is energized when receiver synchronization with incoming data has been lost and subsequently recovered and remains on until the RESET/RESYNC switch is actuated. If the Test Set is in the VIOLATIONS or APS mode, LOST SYNC is held on.

(e) LOST POWER: is energized as the Test Set is turned on, or when a power disturbance of sufficient magnitude to invalidate data is detected. In either case, it remains on until the RESET/RESYNC switch is actuated.

(f) ALL 1's: is energized after a consecutive string of one hundred 1's have been detected. The detection of a zero immediately resets internal circuits. However, the indicator is maintained for 100 MS to assure visibility of minimal length all 1's patterns.

3.1.20 POWER: The Test Set may be powered by either 115 VAC ±15% 47 - 63 Hz or 48 VDC ± 4VDC. Each power supply is separately fused with spare fuses mounted in the dust cover. The AC input is a recessed male connector which mates with one end of the Test Set's power cord. The DC power is applied to the Test Set through a WE-310-type jack. Direct current

powering is intended to be supplied from the 48V, positive ground, Central Office battery. Battery -48 is applied to the plug tip (T). Power cords should be mated to the Test Set first, followed by the power source.

The Test Set is protected against simultaneous operation from AC & DC sources. However, this mode of power operation is not recommended.

3.2 PRINTER/REMOTE INTERFACE (Option P)

Listed in Table 3-3 are all of the signals appearing on the Interface Connector, their specific functions, and pertinent details of the interface circuitry within the Test Set itself. External connection to the Printer/Computer Interface Connector is made by using an Amphenol No. 57-30500 (or equivalent) connector.

3.2.1 Remote Control: The Test Set may be placed under remote control by placing the front panel switches in their open-circuit positions and manipulating the control lines via the interface connector. The correct switch positions for remote control are listed in Table 3-2, and the functions of the control lines are listed in Table 3-3. All control lines are TTL compatible and may be interfaced with TTL driver circuits. RESET/RESYNC and Pin 15 must be driven by a buffer gate, contact closure, or transistor switch rather than by a standard TTL driver. This results from the requirement on the driver to sink 25 mA, which is equivalent to a fan-out of fifteen standard TTL loads.

Table 3-2: Remote Control Switch Position

Switch	Position
MODE VIOLATIONS/ERRORS/APS	APS
SEQUENCE	START

When the Test Set is under remote control, a new test may begin, or a test in process may be aborted, by operating the RESET/RESYNC line. This is equivalent to operating the corresponding front panel switch. When resetting the Test Set, a ground should be applied to Pin 15 for a period of not less than 10 msec. A new test will automatically start within 0.7 sec of the time when pin 15 is again open-circuited. The start of the new test will be signified by the lighting of the COUNT indicator and a ligical 0 on pin 18 of the interface connector.

The end of the test or count period will be signified by the extinguishing of the COUNT indicator on the front panel, the return on pin 18 to a logical 1, and the leading edge of the 100 msec print pulse on pin 38.

Table 3-3: Printer/ Computer Interface Connector - Signals and Pin Assignments

Pin No.	Signal ID	Signal Function	Interface
1	$10^0 - \bar{1}$	Units digit, BCD inverted, A bit	TTL output
2	$10^0 - \bar{2}$	Units digit, BCD inverted, B bit	TTL output
26	$10^0 - \bar{4}$	Units digit, BCD inverted, C bit	TTL output
27	$10^0 - \bar{8}$	Units digit, BCD inverted, D bit	TTL output
3	$10^1 - \bar{1}$	Tens digit, BCD inverted, A bit	TTL output
4	$10^1 - \bar{2}$	Tens digit, BCD inverted, B bit	TTL output
28	$10^1 - \bar{4}$	Tens digit, BCD inverted, C bit	TTL output
29	$10^1 - \bar{8}$	Tens digit, BCD inverted, D bit	TTL output
5	$10^2 - \bar{1}$	Hundreds digit, BCD inverted, A bit	TTL output
6	$10^2 - \bar{2}$	Hundreds digit, BCD inverted, B bit	TTL output
30	$10^2 - \bar{4}$	Hundreds digit, BCD inverted, C bit	TTL output
31	$10^2 - \bar{8}$	Hundreds digit, BCD inverted, D bit	TTL output
7	$\overline{\text{OVERFLOW}}$	Logical 0 when OVERFLOW indicator on	TTL output
18	$\overline{\text{COUNT}}$	Logical 0 when COUNT indicator on	TTL output
35	$\overline{\text{NO DATA}}$	Logical 0 when NO DATA indicator on	TTL output
8	$\overline{\text{NO SYNC}}$	Logical 0 when NO SYNC indicator on	TTL output
9	$\overline{\text{LOST POWER}}$	Logical 0 when LOST POWER indicator on	TTL output
10	$\overline{\text{ALL 1's}}$	Logical 0 when ALL 1's indicator on	TTL output
15	RESET/RESYNC	Ground to Reset Test Set	Switch, 15 TTLS inputs 10K ohm to +5V

Table 3-3: Printer /Computer Interface Connector - Signals and Pin Assignments (cont)

Pin No.	Signal ID	Signal Function	Interface
45	VIOLATIONS/APS	Ground or logical 0 for violations both 45 and 44 open or logical 1 for APS	4 TTLS inputs 2K to +5V
44	ERRORS	Ground or logical '0' for Errors	4 TTLS inputs 2K to +5
16	$\overline{\text{NO TR}}$	Ground or logical '0'	1 TTLS input 10K to +5
41	$\overline{\text{TR}}$	Ground or logical '0'	1 TTLS input 10K to +5
17	$\overline{\text{NO RST}}$	Ground or logical '0'	1 TTLS input 10K to +5
40	$\overline{\text{RST}}$	Ground or logical '0'	1 TTLS input 10K to +5
	START	Pins 16, 17, 40, 41 at +5 or logical '1'	
46	EXT. ERRORS	For each negative transition of a clock signal one error will be inserted into the transmitted data.	1 TTLS input, 10K to +5
47	$\overline{\text{ZERO SUPPRESS}}$	Ground or logical '0' will convert the T1C quasi-random pattern from nineteen consecutive zero format to a restricted fourteen consecutive zero format.	1 TTLS input 10K to +5
48	$\overline{\text{ERROR STRAP}}$	Ground or logical zero will permit APS error rates (SEQUENCE, RANGE, 51A/STD switches) to be used in VIOLATIONS and LOGIC modes in addition to APS.	1 TTLS input 10K to +5V
21	$\overline{\text{INSERT ERRORS}}$	Ground or logical '0' to insert 8 errors per 10^6 bits	3 TTLS inputs 2K to +5V
11	RECEIVER WORD SYNC	Normally high, pulls to ground for 324 nsec every 1,048,575 bits	Transistor sw to gnd, 75 ohm to +5V
14,39	GND	Chassis ground and signal return	
36	+5V	+5V output for reference only ($<$ 50 mA)	

Table 3-3: Printer/Computer Interface Connector - Signals and Pin Assigments (Cont)

Pin No.	Signal ID	Signal Function	Interface
37	CARRY	Normally low, goes to logical '1' for 10 msec when 3-digit error counter overflows	TTL output
38	PRINT	Normally low, goes to logical '1' for 100 msec at end of count interval	TTL output
43	ALL 1's PATTERN	Ground or logical '0', Test Sets DS1/DS1C output pattern is converted to bipolar all 1's	1 TTLS input 10K to +5

3.2.2 BINARY-CODED DECIMAL (BCD): The three decimal digits of the internal error counter and display are brought out on twelve interface lines. The information is presented in 1248, BCD, code and all twelve outputs are in the inverted sense. These signals are buffered by TTL inverters located on the BUFFER/APS Module of the Test Set for the purpose of protecting the internal circuitry; therefore, these lines are capable of sinking 8 mA and sourcing 200 uA, which is equivalent to ten standard TTLS loads. Care should be taken to avoid conditions which exceed these current levels or cause the voltage applied externally to go beyond the range of 0 to +5 V dc.

3.2.3 INDICATOR LIGHTS: The information presented on six of the eight Receive status indicators is duplicated in these six signals. The information is presented such that a low level or logical zero is presented when the corresponding indicator is lighted. Like the BCD lines above, these are buffered by TTL inverters in the BUFFER/APS Module of the Test Set.

3.2.4 CONTROL: These interface lines provide parallel access to the major front panel switches of the Test Set. They may, therefore, serve as outputs for monitoring switch settings or as inputs for remote control of the Test Set. If the front panel switches are set as listed in Table 3-2 +5 V will appear on all input lines and remote control may be affected via contact closures or NPN open-collector switching to ground.

These input lines are connected directly to one or more TTL inputs without input buffering (ref. Figure 3-1). The front panel switch to ground and 10K ohms resistors to the +5 V supply are also connected to these inputs. Any device driving these inputs must be capable of sinking current equal to 1 mA plus 0.8 mA times the number of TTL inputs indicated in Table 3-3. Since the 10K ohm resistive pull-up is provided internally

and the control lines may be shorted to ground by the front panel switch, the driving device should not be capable of sourcing current. The voltage of the inputs, including transients, must be restricted to between ground and the internal supply, as provided on pin 36 of the Interface Connector.

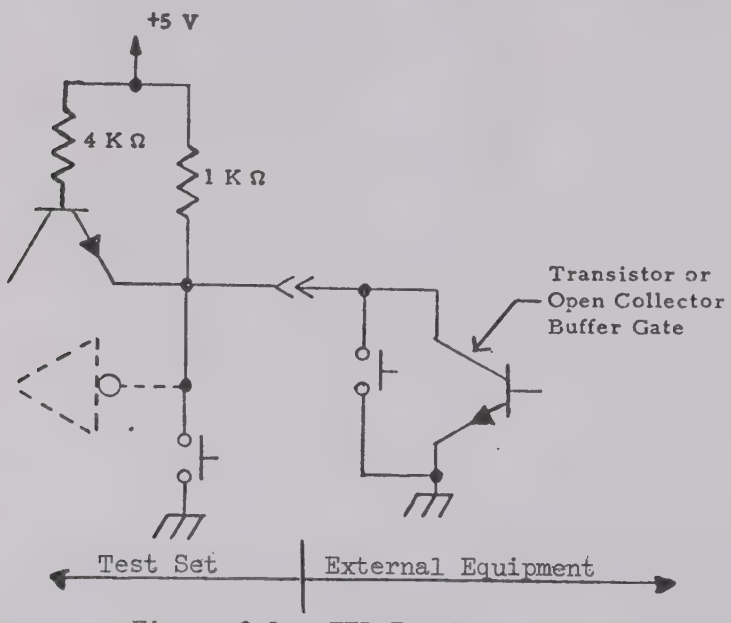


Figure 3-1: TTL Inputs

3.2.5 +5 V DC: The internal logic supply of the Test Set is provided on pin 36 of the Interface Connector for reference purposes. It should be used by the external interface circuitry to signify the maximum external voltage that can be tolerated at most of the TTL inputs and outputs. This includes the possibility in which the external circuitry is powered and the Test Set is not powered, or vice versa. The internal supply and pin 36 are separated by a 1 K, 1/4 W resistor (R38). If it is necessary to by pass this resistor, caution should be exercised not to exceed a maximum current of 50 mA.

3.2.6 PRINT AND CARRY OUTPUTS: The carry output generates a 10 msec pulse each time the 3-digit display of the Test Set overflows. The 100 msec print pulse is generated at the end of each count interval when the COUNT indicator is extinguished. Both outputs are derived from TTL devices and normally remain low.

3.2.7 AUXILIARY OUTPUT (WORD SYNC): The auxiliary output is derived from NPN transistor switches with 75 ohm pull-up resistors to the +5 V supply. The transistors should not be required to sink more than 30 mA of current through the Interface Connector and the voltages must be restricted to between ground and +5 V. These outputs may be shorted to each other or to ground without danger of damage to the internal circuitry.

3.3 Applications

The Bowmar Model 273 Digital Carrier Analysis Test Set can be used to test any Digital Transmission System or component accepting a T1 (DS1, 1.544 mbs) or T1C (DS1C, 3.152 mbs) bipolar signal. This Test Set performs bipolar violation and logical error measurements. Bipolar violations are defined as transmission format errors where two or more '1's are transmitted with the same polarity, consecutively irrespective of zero content. Logical errors occur when a data bit is mistakenly converted from a '1' to a '0' or a '0' to a '1' by a malfunction or noise within the communications sytem. Logical error detection requires that the information content of the data being transmitted is known. The Bowmar 273 contains a quasi-random signal source (QRSS) identical to the Western Electric J98710R T1 QRSS. This test source provides the Data Base used in logical error measurements and presents a realistic stress on the equipment under test.

The Bowmar Model 273 may be used to test: T1 and T1C Carrier Systems; Digital Radio Systems; Lenkurt Duo Binary Systems; AT&T Digital Data System (DDS); APS Tests on T1 Outstate, DDS, TSPS, or any system using Automatic Span Line Protection Switches; Multiplexers such as M12 and M1C.

This Applications Section is not intended to give the operator a detailed set of steps to follow. Rather the intent of this Section is to acquaint the operator with a wide variety of test schemes and general methods. For specific details consult the appropriate Bell System Practice.

3.3.1 General Usage:

(a) BIT RATE Switch (T1/T1C)
This control selects either T1 (DS1, 1.544 mbs) or T1C (DS1C, 3.152 mbps) data transmission rates. The data rate chosen must agree with that of the system under test.

(b) Monitor Jacks and Cross Connect Points.
The Receiver of the Test Set can be made to either bridge or terminate the line which is connected to the DS1/DS1C input 310 jack. The BRIDGE/TERM switch makes this selection. In the TERM position the Receiver presents an impedance of 100 ohms ± 5% while the BRIDGE position represents more than 5000 ohms.

When operating from monitor jacks, the BRIDGE/TERM switch must be in the BRIDGE position and cable between the monitor jack and the Test Set should not exceed 6 ft. A standard termination should be present at the corresponding cross connect point.

At Cross Connect points the TERM (100 ohm) position should be selected to provide the proper line terminating impedance. There are no cable length constraints as required in the BRIDGE position.

The BRIDGE/TERM switch determines the Receive DS1/DS1C input impedance only. The DS1/DS1C transmitter outputs have a constant source impedance of 100 ohm ± 5%.

(c) Receiver Status Indicators
In the VIOLATIONS or APS test mode, both the NO SYNC and LOST SYNC indicators are held "ON", and are not to be considered a test failure.

Synchronization of the Receiver can only be achieved if the received data is a QRSS pattern identical to Western Electric J98710R, or the output of Bowmar Model 273 or 271 Test Sets. Since violation testing is independant of the data content, the 273 Receiver circuits will make no attempt at synchronizing when the mode switch is either in the VIOLATIONS or APS positions. Bowmar has chosen to hold these indicators ON to maintain functional compatibility with the Western Electric KS-20775 L1 and L2 specifications.

(d) Violations Test
Some T-Carrier equipment (e.g. multiplexers) remove bipolar violations. It is, therefore, possible when inserting violations into the test pattern that no violations, or something other than that anticipated, may be detected at the far end station.

(e) Errors, Block Errors, and EXT. Clock

1. Errors/Block Errors. These two BNC connections are outputs which may be connected to an external counter. The errors connection presents a Hi (+5V) to Low (Gnd) transition for every error detected by the Test Set regardless of the position of the DISPLAY FORMAT switch. It can be used when the Test Set's three digit display is not large enough or when a simultaneous count of individual errors and formated errors (error sec, deci sec, or 0.3 ms blank) is desired.

   The Block Errors output presents a Hi to Low transition for errors detected and massaged in accordance with the position selected by the DISPLAY FORMAT switch.

2. EXT. Clock. This input permits the Test Set's transmitter to be synchronized with the communications system equipment under test. The input requires a 3V $\pm$ 1V bipolar all 1's pattern.

3.3.2 General Test Preparation

(a) Check for the presence of the proper fuse.

1. AC line operation, 3AG, 1/2A, Slo Blo, located on front panel.

2. DC, 48V central office battery operation, 3AG, 3/4A, Slo Blo, located at rear of outer case.

Note: Spare fuses located in cover.

(b) Connect the power cord between the Test Set and a suitable power outlet.

1. AC power, 115 VAC $\pm$ 15%, 47 - 63 Hz, Single Phase.

2. DC power, -48VDC $\pm$ 4V , positive bat. ground, connected through a WE310 jack,tip to -48VDC,positive ground to sleeve.

CAUTION: Power cords should be connected to the Test Set first followed by connection to the power source.

(c) Set Power switch to On.

(d) Set the BIT RATE switch (T1/T1C) to correspond with the system under test.

(e) Connect a patch cord between the Test Set's DS1/DS1C input to either a monitor or cross connect jack.

Set the BRIDGE/TERM switch to BRDIGE for all MONITOR connections and restrict the patch cord cable length to a maximum of 6 ft. At cross connect jacks, set this switch to TERM.

(f) Set the DISPLAY INTERVAL control for comfortable display viewing, between 1 and 10 seconds or hold.

(g) The ERROR FORMAT switch should generally be set to INDIVIDUAL such that all errors detected are displayed. Certain tests and conditions where large error bursts can be expected will require use of the protected error (DISPLAY FORMAT switch) positions.

(h) The COUNT INTERVAL (BITS) control setting is dependent on the expected or actual system error rate.

Note: A count of 10 on the Display and a switch setting of 10^8 equates to a error rate of less than 10^{-7}. This mathematical manipulation is true of all switch position/display counts combinations.

(i) The SYNC MODE switch should generally be set to AUTO. This switch is applicable to logical error measurements only.

(j) Operate the RESET/RESYNC switch. This starts a new test interval. The count registered on the DISPLAY when the COUNT indicator is OFF, in conjunction with the COUNT INTERVAL chosen, determines the error rate.

(k) Line Identification. A through transmission path can be varified by using the Test Set's ability to insert errors into its transmitted QRSS data pattern. Holding the SELF TEST switch in the INSERT ERRORS position injects 8 errors per 10^6 bits. Detection of this error rate at the far end varifies a through transmission path. Caution should be exercised in the VIOLATIONS mode as some communications equipment (e.g. Multiplexers) remove bipolar violations. The LOGICAL errors mode should ideally be chosen.

(l) Other control settings depend on the type of tests to be conducted.

3.3.2 System Tests

3.3.2.1 End-To-End Error Rate Measurements

The Test Set's Receiver and Error Detection Circuits are utilized in end-to-end testing. The Test Set is connected to either a MONITOR or CROSS CONNECT jack. Data is placed on the Line/System under test at the far end using either a Western Electric J98710R quasi-random signal source, a second Bowmar Model 273 or a Bowmar Model 271A,B, C (KS-20775 L1, L2). Either LOGICAL ERROR or VIOLATIONS measurements can be made.

3.3.2.2 Loop Back Error Rate Measurements

Loop Back tests require the far end to be patched back to back. The Transmitter (DS1/DS1C output) of the Test Set is connected to the line at the near end, supplying a quasi-random signal source. The Test Set's Receiver is connected to either a monitor or cross connect access jack. Either VIOLATION or LOGICAL ERROR measurements may be made.

3.3.2.3 Monitor In-Service Bipolar Violations

Bipolar Violations may be measured at any time on an in-service line without disturbing that line. The 273's DS1/DS1C input is connected to a MONITOR jack. The BRIDGE/TERM switch must be in the BRIDGE position.

3.3.2.4 Multiplexer Tests

Multiplexers, such as M12 and M1C, may be tested by looping the multiplexer back on itself and applying a test signal to its inputs. The 273 provides up to four independent DS1/DS1C outputs which may be connected to a multiplexers input ports. Connecting the Test Set's DS1/DS1C input to each of the multiplexers output ports completes the test data path. Multiplexers remove bipolar violations, therefore, logical error testing should be performed.

3.3.2.5 Automatic Span Line Protection Switch (APS) Tests

At present, systems such as T1 outstate, DDS, and TSPS utilize Automatic Span Line Protection Switches (APS). The majority of switches in use may be classified as two types. The first follows the specifications outlined by Bell Telephone Laboratories which refers to a hysterisis switch, referred to by Bowmar as STANDARD (STD). The second type was devloped prior to BTL's initial specification and is referred to by Bowmar as 51A. The wide acceptance of the 51A equipment by the operating companies has resulted in BTL recognition with appropriate specification standards.

The 273 is connected to an in-service line such that it is in series with the data path for one direction of communication. The 273's MODE switch is set for APS and BRIDGE TERM switch to BRIDGE. A cable is connected between the 273's input and a monitor jack. A load plug is inserted into the corresponding output jack to preserve line impedance and one of the 273's four DS1/DS1C outputs is connected to the Cross Connect input jack. The 273's RANGE switch should be set to match the Error Rate Set on the Span Line Switch (10^4, 10^5, 10^6, 10^7, 10^3 available for STD only). The setting of the STD/51A switch should correspond to the type of equipment being tested.

Set the SEQUENCE Switch to start and observe that the alarm indicators on the Span Line Switch equipment show the line to be tested as, in-service. Set the sequence switch to NO TR. (NO TRANSFER). Equipment alarms should show that the line under test remains in service. Place the SEQUENCE switch to TR (TRANSFER). Alarm indicators should identify the line under test as failed and data switched to the stand by line. Rotate the SEQUENCE switch to NO RST (NO RESTORE). The alarm status for TR should hold. Set the SEQUENCE switch to RST (RESTORE). Normal service should return to the line under test

4.0 THEORY OF OPERATION

General

Refer to the Block Diagrams (Figures 4-1 and 4-2) and the Schematics of Section 6 to correlate descriptions offered in this section.

4.1 Transmitter

The Transmitter section of the Digital Carrier Analysis Test Set is a DS1/DS1C (T1, T1C) type test source. The data base for the transmitted signal is provided by a continuously repeating Quasi-Random sequence identical to that provided by Bell System Test Sources (e.g. WE J98710R, T1 Signal Source). When operating in the APS mode, the transmitted data is equal to that received from a system under test. The transmitter is also capable of inserting errors (bipolar violations or logical bit errors) into the transmitted data base.

The T1 (DS1) transmitter output is a 1,544 mbps, 3 volt, bipolar, return-to-zero signal with trailing edge overshoot. The Quasi-Random signal source provides a 1,048,575 bit repeating pattern limited to fourteen consecutive zeros.

The T1C (DS1C) transmitter output is a 3,152 mbps, 3 volt, bipolar, return-to-zero signal. The Quasi-Random signal source provides a 1,048,575 bit repeating pattern with up to nineteen consecutive zeros.

Controlled error insertion makes it possible to provide this Test Set with a self test feature, line identification, and span line automatic protection switch (APS) testing. When the two DS1/DS1C inputs are removed the Test Sets' Transmitter is automatically looped back to the Receiver by an internal relay. Operating the SELF TEST switch to insert errors instructs the Transmitter to insert four pairs of errors every complete cycle of the Transmitter's sequence generator. These errors will be detected by the Receiver and displayed, providing a method of self test. When testing T-Carrier Systems it is possible to confirm a data path, end-end or loopback connection, by inserting this error pattern and monitoring for its presence at the terminating station.

The Quasi-Random sequence generator produces four patterns of seventeen or more consecutive zeros each cycle. A pair of errors is inserted each time one of these patterns is detected, thereby producing a fixed error rate of eight errors per cycle, (1,048,575 bits).

Logical error insertions of a zero-to-one and a one-to-zero conversion are performed by altering the function of the circuit which limits the output sequence to a maximum of fourteen consecutive zeros. This alteration is accomplished without violating either the fourteen-zero restraint (T1) or the bipolar format.

Bipolar violations consist of four consecutive ones, the first two of one polarity, and the second two of opposite polarity. This is accomplished by inhibiting the Bipolar Generator which normally alternates the polarity of each consecutive one, whether or not they are interspersed with zeros.

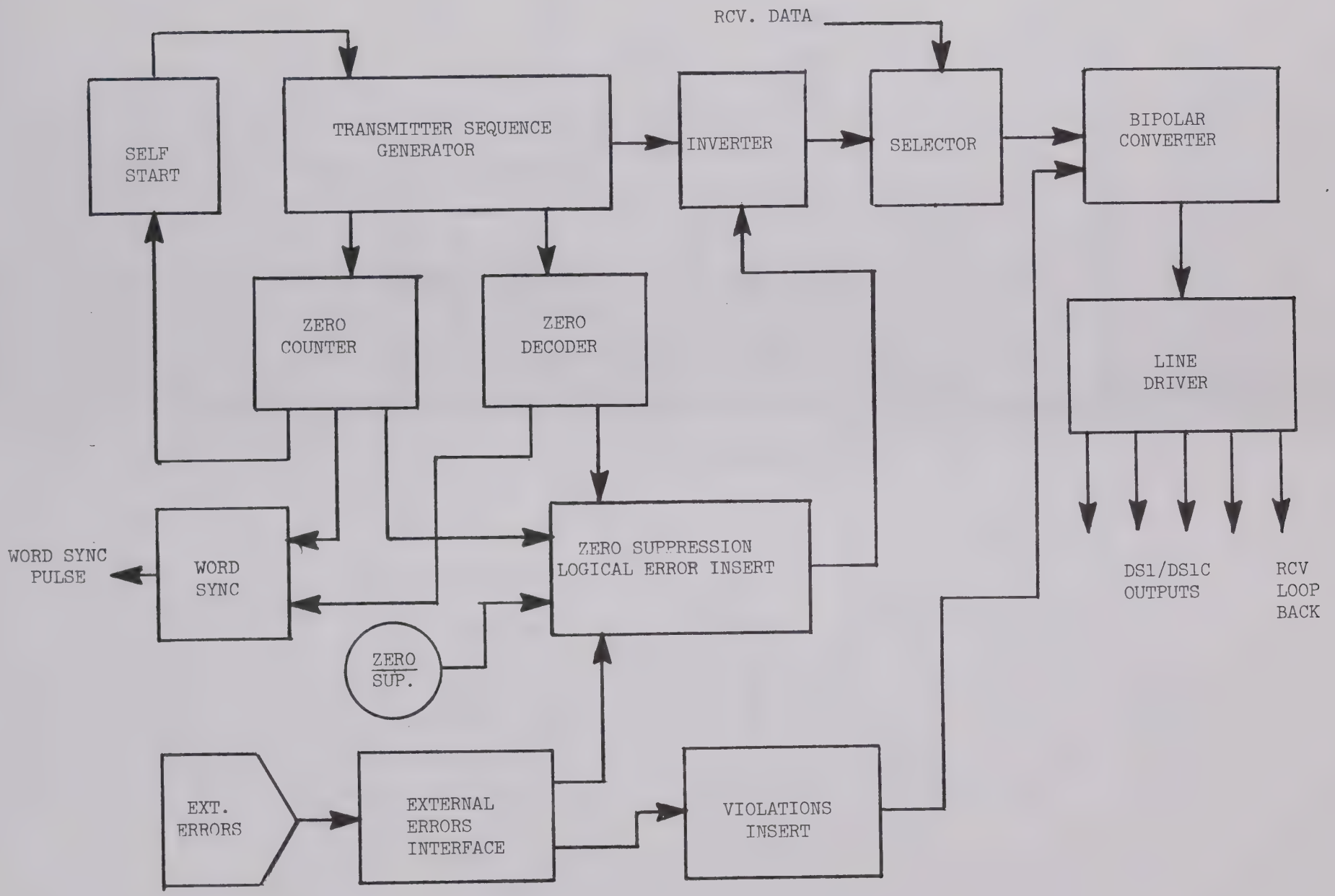
The Chart below illustrates a typical condition of eighteen zeros in the Sequence Generator. Note that the first four zeros when operating at the T1 rate have been converted to 1's to satisfy the 14 zero constraint. This Chart defines the format used for 14 zero limiting and error insertion.

Description		Data Stream Segment
Any condition of 17 or more zeros (18 shown) in Sig. Gen. output:	1st out	1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1
Corrected output (without errors):	T1	1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1
	T1C	1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1
Corresponding Xmitter output, Bipolar Format:	T1	+ - + - + 0 0 0 0 0 0 0 0 0 0 0 0 0 - + -
	T1C	+ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 - + -
Gen. output with Logical Errors:	T1	0 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1
	T1C	0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1
Corresponding Xmitter output, Bipolar Format:	T1	0 + - + - + 0 0 0 0 0 0 0 0 0 0 0 0 0 - + -
Errors:		X X
Bipolar Format:	T1C	0 0 0 0 0 + 0 0 0 0 0 0 0 0 0 0 0 0 0 - + -
Corrected Xmitter output with Bipolar Violations:	T1	+ + - - + 0 0 0 0 0 0 0 0 0 0 0 0 0 - + -
Violations:		X X
Bipolar Violations:	T1C	+ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 + - -
Violations:		X X

The rate at which violations are inserted by the APS circuits is determined by an independant oscillator and programable divider circuit. The APS RANGE and SEQUENCE switches define the clock rate exiting the divider circuit. Each complete clock cycle introduces one violation in the transmitted output.

The Transmitter Error Insertion circuits can be activated by an external signal applied to the Printer INTERFACE connector Pin 46 (option). A single Error, Violation or Logical as determined by the MODE switch, will be inserted into the transmitted output for each negative transition of the EXT. ERROR clock source.

TRANSMITTER BLOCK DIAGRAM FIG. 4-1A



TRANSMITTER BLOCK DIAGRAM FIG. 4-1B

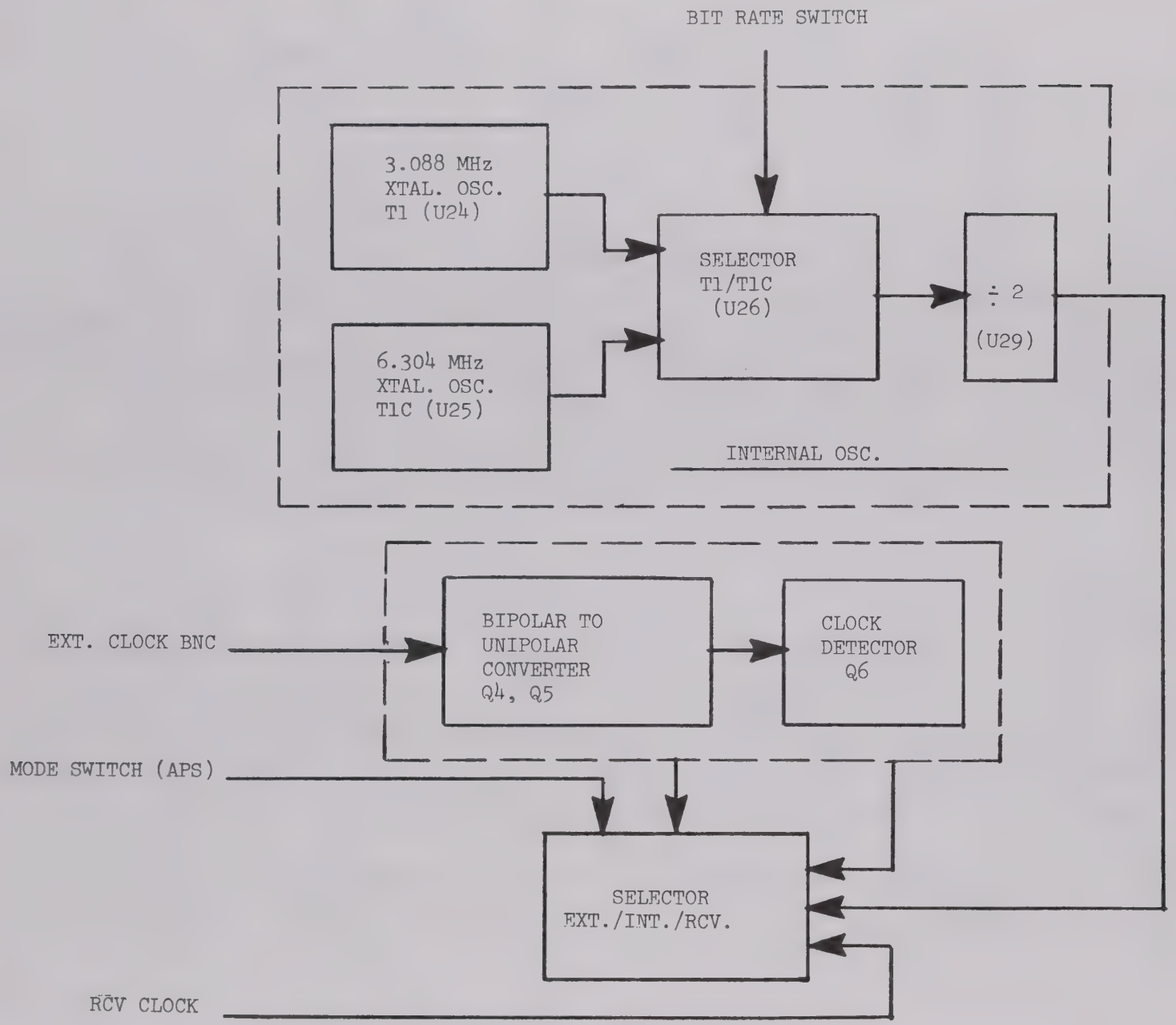
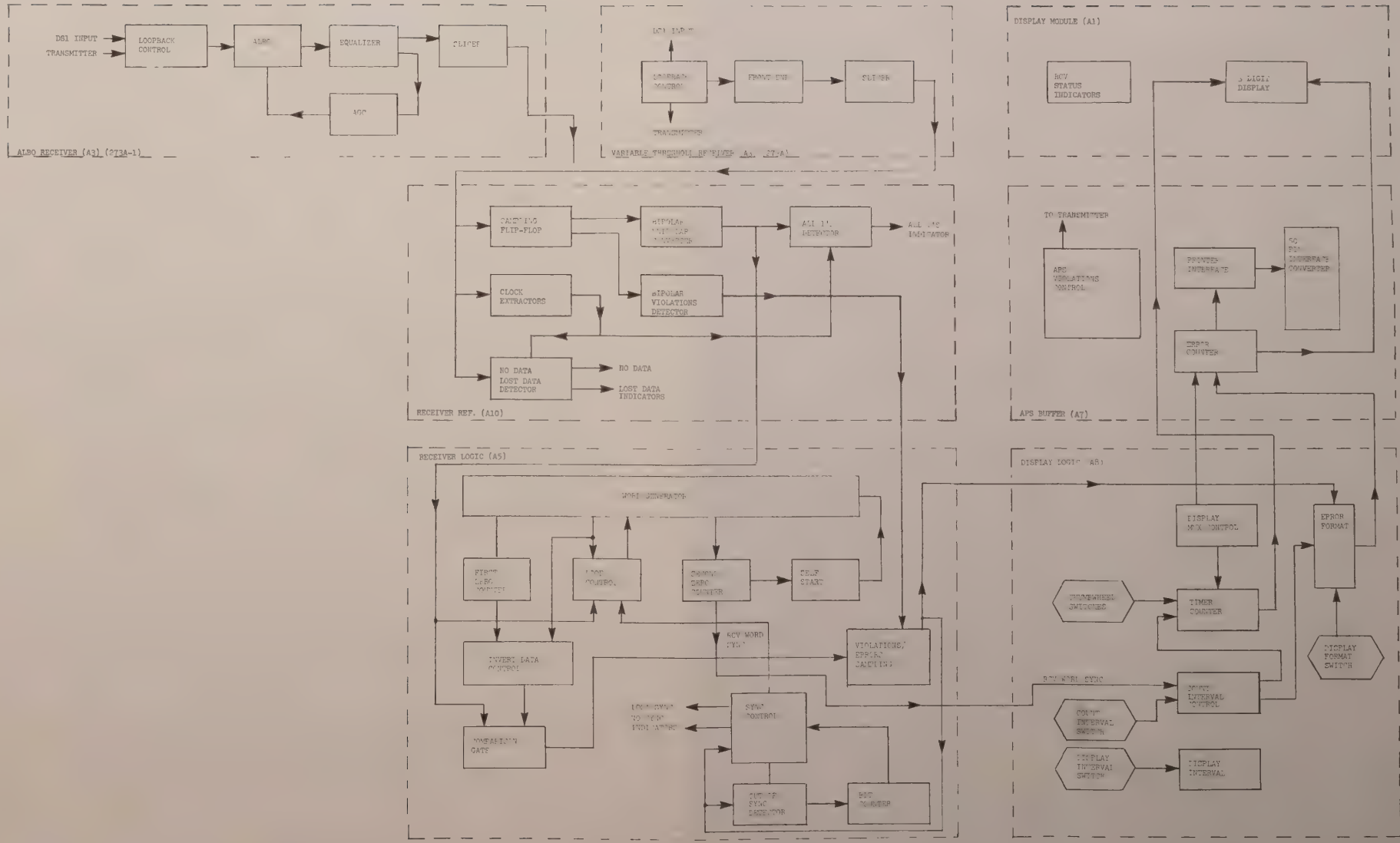


FIGURE 4-2A


DS1 INPUT
TRANSMITTER
LOOPBACK CONTROL
AGC
EQUALIZER
SLICER
AGC
ALBO RECEIVER (A3) (2T3A-1)
LOOPBACK CONTROL
FRONT END
SLICER
TRANSMITTER
VARIABLE THRESHOLD RECEIVER (A3) (2T-A)
DISPLAY MODULE (A1)
RCV STATUS INDICATORS
3 DIGIT DISPLAY
SAMPLING FLIP-FLOP
BIPOLAR VIOLATION DETECTOR
ALL 1's DETECTOR
ALL 1's INDICATOR
CLOCK EXTRACTORS
BIPOLAR VIOLATIONS DETECTOR
NO DATA LOST DATA DETECTOR
NO DATA
LOST DATA INDICATORS
RECEIVER REF. (A10)
TO TRANSMITTER
APS VIOLATIONS CONTROL
PRINTER INTERFACE
DC DIA CONVERTER
ERROR COUNTER
APS BUFFER (A7)
RECEIVER LOGIC (A5)
WORD GENERATOR
ERROR DETECTOR
LOOP CONTROL
CHANNEL DETECTOR
DELAY START
INVERT DATA CONTROL
RCV WORD SYNC
VIOLATIONS, ERROR, ALARMS
LOSS SYNC
RE-SYNC PULSE
SYNC CONTROL
COMPARATOR GATE
SYNC DETECTOR
BIT COUNTER
DISPLAY LOGIC (A8)
DISPLAY MUX CONTROL
ERROR FORMAT
TIMER COUNTER
DISPLAY FORMAT SWITCH
RCV WORD SYNC
COUNT INTERVAL CONTROL
COUNT INTERVAL SWITCH
DISPLAY INTERVAL SWITCH
DISPLAY INTERVAL

4.2 Receiver

Evaluation of data from a system under test takes place in the Receiver. Incoming data, in Bipolar format, is processed by an AUTOMATIC LINE BUILDOUT (ALBO) circuit in the Model 273A-1 to remove amplitude and phase delay degradation imposed by cable characteristics. A slicer converts the processed received signal to a pulse format required by TTL logic. In the Model 273A the ALBO is replaced by a Receiver with slicing threshold proportional to the peak of the received signal, variable threshold.

Clock pulses for the Receiver are taken directly from the reshaped data by a clock extractor circuit. When data is discontinued or interrupted, a NO DATA Detector signals the NO DATA indicator and inhibits Clock pulses to data processing circuits. If data is re-established the NO DATA indication is removed and a LOST DATA indicator asserted.

When the content of the received data is such that it contains only 1's bits, an ALL 1's indication is established. A pattern of 100 consecutive 1's must be detected.

Reshaped data, after sampling, is directed to the BIPOLAR VIOLATIONS Detector and the Bipolar/Unipolar converter.

The first circuit looks for two consecutive 1's of the same polarity, while the second circuit converts data from bipolar to unipolar format. The outputs of these two circuits are then ANDed. If the mode switch is set for ERRORS, the received data, in unipolar format, is routed to the Receiver Sequence Generator. This Generator differs from its Transmitter counterpart only in its monitor points and in a modified feedback loop; otherwise, it is capable of the same 1,048,575 bit test pattern. Its purpose is to provide a base pattern for checking the incoming unipolar data for logical errors by a process described in later paragraphs.

If the mode switch is set for VIOLATIONS, unipolar data is ignored, and the output of the Bipolar Violations Detector is forwarded directly to the Error Format Circuits, Counter and Display. In this situation, the Receiver Sequence Generator is made to continuously cycle simply to provide a time base for test length selection via the COUNT INTERVAL (BITS) switch. When operating in this capacity, the Sequence Generator is self-starting, but it does not attempt to synchronize to the unipolar data stream.

The key difference between the Transmitter and Receiver Sequence Generators is the latter's modified feedback loop, which is arranged to be open or closed. When it is closed the two generators behave identically, as self-starting generators for the 1,048,575 bit test pattern; when it is open it is injected with the unipolar data stream. If the unipolar data contains no errors, it deceives the Receiver Sequence Generator into behaving as a closed loop device, thus synchronizing it with the incoming data.

Synchronization of incoming unipolar data with the Receiver Sequence Generator may be initiated automatically or manually, depending on the setting of the SYNC MODE switch. In the MANUAL mode, loss of sync is made apparent by the NO SYNC indicator; resynchronization is gained by actuating the RESET/RESYNC switch. Once synchronization is achieved

and the Sequence Generator loop is closed, and the Generator output becomes its own natural pattern. The incoming unipolar data is then compared with this output and checked for logical error content. Logical errors are fowarded to the error format circuits, counted and displayed.

The DISPLAY FORMAT switch determines the type of weighting (individual, error sec, error decisec, 0.3 ms blank) which is applied to the detected errors (logic or violations) before being displayed. The effects of the DISPLAY FORMAT Circuit are described in Section 3.1.5.

Test duration is determined by the COUNT INTERVAL Control. The Display registers errors per one, ten, one hundred or one thousand cycles of the Receiver Sequence Generator by selection of the 10^6, 10^7, 10^8 or 10^9 positions respectively of the COUNT INTERVAL (BITS) switch. CONT or TIMER positions are used for MANUAL mode operation or for very long time intervals.

When operating in the APS mode, violations are introduced into the data by the APS Violations Control Generator. Received data is forwarded directly to the Transmitter from the Bipolar/Unipolar converter. The APS Violations Control determines the rate at which Bipolar violations will be introduced into the received data by the Transmitter's Bipolar Converter. In this mode, the Test Set acts as a repeater by re-transmitting data which it has received from equipment under test. The APS RANGE, SEQUENCE and STD/51A switches determine the violation rate introduced.

4.3 TRANSMITTER CIRCUITS (A4 MODULE)

4.3.1 Internal Oscillator

Either of two crystal oscillator circuits (U24, U25) are selected by steering logic (U26) and divided by a single flip-flop (U29).

The flip-flop output provides a symmetrical clock at either 1.544 MHz (T1) or 3.152 MHz (T1C) as selected by the BIT RATE (T1/T1C) switch.

The crystal oscillator operates in series mode with two, tandem connected, TTL inverters providing the necessary positive feedback path. A third inverter in conjunction with resistors R34 or R33 determine the crystal drive current. Adjustable capacitors C14 and C18 are frequency trims for the 3.088 MHz and 6.304 MHz crystals respectively.

4.3.2 External Clock

The external clock circuit converts (Q4, Q5) a 3 $\pm$ 1 V Bipolar, all 1's, signal to a square wave for use as the Transmitter clock. A detector (Q6) senses the presence of the external clock and signals the INT/EXT/RCV Selector, which automatically switches from Internal to External clock.

The secondaries of transformer T2 present an inverted and non-inverted, ground referenced, Bipolar signal to the bases of transistors Q4 and Q5 respectively. Transistor Q4 conducts only for negative pulses of the external clock with Q5 conducting for positive pulses. The collectors of Q4 and Q5 are connected together to form a wired-or output.

Transistor base resistor/capacitor (R35/C21, R36/C22) networks reduce the effects of base storage to improve switching speed. Resistors R45 and R46 determine the circuit input impedance.

The converted square wave at the collectors of Q4 and Q5 is inverted and passed to the Detector Circuit (Q6). With no external clock, the transistors Q4 and Q5 are cut off. Transistor Q6 is off and capacitor C23 is charged to +5 volts through R43.

When the external clock is present, Q6 is switched at the clock rate discharging C23 through R42. A near ground voltage across C23 signals the INT/EXT/RCV Selector to select the external clock.

4.3.3 Selector INT/EXT/RCV

This Selector (U27) determines whether the internal crystal oscillators external clock or receiver clock will control the transmitter circuits. The external clock detector signal is the dominant control followed by the APS position of the MODE switch. In the APS MODE the Transmitter is controlled by the receiver clock.

4.3.4 Sequence Generator

Quasi-random test patterns, or sequences, issued by the Transmitter are derived from a 20-stage shift register generator whose feedback is taken from stages 17 and 20. The Generator is contained by U1A through 4B, with feedback directed through the exclusive-OR circuit of U5A.

The Sequence Generator provides a continuously repeating sequence of 1's and 0's. Each sequence is made up of all but one of the 2^{20} possible combinations of 20-bit states, for a total of 1,048,575 bits. The one exception is the all-zero state in which the Generator, by nature of its circuitry, will not function. In a situation where all-zeros might occur, a Self Start circuit (Ref. 4.3.6) is available to respond with injection of a 1 to unlock the Generator. During normal operation, the maximum count of 0's in the Generator is nineteen.

The main output of the Generator is taken from the 20th stage. Auxiliary outputs from the 2nd, 3rd, and 4th stages enable monitoring of the serial progression of bits through Generator stages for purposes of determining self start, zero suppression, error insertion, etc. Each generated bit shifts a stage at a time with each Clock pulse.

Since auxiliary outputs are several stages ahead of the main output, they offer a preview of the output sequence of bits. This feature permits the necessary advance notice required for such actions as the fourteen-zero constraint, or the seventeen or more 0's state for error insertions, etc.

4.3.5 Zero Counter

A zero counter monitors the number of zeros passing stage four of the sequence generator. The counter is actually incremented by clock pulses, but is reset by registration of a 1 so that the accumulated counts represent a series of 0's.

The Binary Counter U8 is preset with a count of 1. After the passage of 15 consecutive zeros U8 sets flip-flop U11a. One half clock period later U11b is set. The outputs from these flip-flops control zero suppression and error insertion logic.

4.3.6 Self Start

Self starting is initiated through a single gate (U7A) by a count of twenty from the Zero Counter. This count is possible only if the Sequence Generator is locked into the all-zero state and Clock pulses continue to increment the Zero Counter. The only opportunity for all-zero lock-up and self starting occurs when the Error Rate Test Set is switched on for use.

As described earlier, the Sequence Generator cannot function in an all-zero state, therefore, upon registration of twenty 0's by the Zero Counter, the Self Start circuit is activated to force a 1 into the input of the 1st stage of the Generator. This resets the Counter and stimulates the Generator into normal operation.

4.3.7 Zero Detector

The Zero Detector (U9B,C, U10) working in conjunction with the Zero Counter identifies patterns of seventeen or more consecutive zeros in the Sequence Generator. A NAND gate U9B looks at the Sequence Generator two outputs earlier than the Zero Counter. This two bit look ahead combined with the fifteen zero detection of the Zero Counter is latched by flip-flop U10. Outputs from this detector control error insertion and Transmitter Word Sync.

4.3.8 Word Sync

A single gate (U9A) with inverter (U22C) make up the Word Sync circuit. This state combines a count of seventeen from the Zero Counter and a two bit look ahead from the Zero Detector. The combination produces a pulse for each pattern of nineteen zeros which occures only once every 1,048,575 bits (a full cycle of the test pattern). Word Sync is used to mark each test cycle and is available as an auxiliary output, TRANSMITTER WORD SYNC.

4.3.9 Zero Suppression/Logical Error Insertion

Zero suppression is a process which limits the number of consecutive zeros produced by the Sequence Generator to conform with accepted Bell System standards. Consecutive zero patterns are limited to fourteen when operated at the T1 Bit Rate. When operating at the T1C Bit Rate, no zero suppression is required resulting in patterns up to nineteen zeros long (maximum permissible sequence generator pattern). A strap option located on the APS/BUFFER module (A7) will assert fourteen zero suppression at both the T1 and T1C rates.

Zero suppression is attained by inverting the data pattern exiting the twentieth stage of the Sequence Generator. The first zeros in excess of fourteen are inverted (0 to 1). This is accomplished by the Zero Counter which identifies zero patterns greater than fourteen two clock periods before the first zero will exit the Generator. Flip-flops U19A, B and U21A form a three bit shift register. Zero suppression information is inserted into the second stage (U19B) through U20A. This signalling is inhibited by U22D when operating at T1C. Flip-flop U19A and other logic operated during logical error insertion. The suppression information arrives at the Invert Gate within two clock pulses synchronously with emergance of the first zero from the Sequence Generator.

Operation of the zero suppression circuits is modified slightly when logical errors are inserted. As discussed in Section 4.1.1, logical errors are inserted by inverting the bit just prior to zero suppression and another just after, for each occurence of seventeen or more zeros. This is accomplished by setting the first and last stages (U19A, U21A) of the zero suppression shift register at the same time the second stage (U19B) is set by zero suppression information. Within one clock pulse the Invert Gate will be signalled to invert the output of the Sequence Generator which is just one bit before the emergence of the Detected Zero Pattern. When the end of the zero pattern is detected by the Zero Counter all inputs to the zero suppression circuit are removed. The next two clock pulses invert the pattern as required for zero suppression. The third clock pulse inverts the first zero of the suppressed fourteen zero pattern producing an error. Patterns of seventeen or more zeros occur four times each generator cycle. Two errors are inserted each pattern for a total of eight errors each cycle of 1,048,575 bits.

4.3.10 Invert Gate

An exclusive-OR gate (U5B) inverts the output of the Sequence Generator when signalled by the zero suppression logic.

4.3.11 Data Selector

A Data Selector composed of U6 directs either the output of the Invert Gate or Received data to the Bipolar converter. When the MODE switch is operated to APS, the Receive data is selected.

4.3.12 Bipolar Converter

The output of the Data Selector is sampled and delayed one-half bit by the sampling flip-flop (U10). The output of the flip-flop is then ANDed with Clock pulses through U22A to obtain a return to zero (RZ) data format for the Bipolar Converter.

A single flip-flop and two gates (U5C, U5D) make up the Bipolar Converter. Its function is to alternate the polarity of all 1's in the test sequence, regardless of the interspersion of 0's; thus, when a 1 is generated of one polarity, the next 1 will have the opposite polarity, whether or not there are 0's between the two 1's.

Bipolarization is triggered by the trailing edge of each 1 in the data stream. At this instant, the flip-flop toggles so that the next 1 is transmitted with the opposite polarity. Two gates, U5C and D, delay the toggle input to the flip-flop slightly to ensure a correct time relationship with the inhibit input from the Bipolar Violations Control Circuit. Outputs from the flip-flop are passed to the line driver to control the polarity of the transmitted signal.

4.3.13 Line Driver

Each of the Bipolar Converters two outputs are directed to a Line Driver U23. The Line Driver contains two AND gates with associated drive transistors. These internal transistors conduct alternately under the direction of the Bipolar Converter and data to be transmitted. Each transistor drives one primary winding of T1.

The transformer is trifilar wound, with two of its winding connected at the center-tapped primary. The third winding serves as the balanced output, which is padded as necessary and distributed to the DS1/DS1C OUTPUT jacks and to the Receiver. Shaping the inherently rectangular signal bits into the T1 pulse shape with trailing edge overshoot is accomplished with a passive RLC circuit (R9, R10, L1, C1) connected across the transformer primary. This wave shaping circuit is connected for T1 (DS1) data rates only. At the T1C rate FET Q1 represents a high source to drain resistance. FET Q1 is controlled by a level shifting circuit Q2 and Q3. The Bit Rate switch (T1/T1C) turns Q2 and Q3 on when operated to T1C. This applies -5 volts to the gate of Q1 turning it off.

The Gas Spark Gap GS1 protects the line driver from large line transient voltages.

Resistors R18 through R27 serve to drop the output voltage to 3 volts peak while providing a measure of isolation between outputs and a 100 ohm output impedance. These resistors link the line driver to the four DS1/DS1C outputs and provides a loopback path from the Transmitter to the Receiver for Self Test purposes.

4.3.14 Violations Control

Operation of the Violations Control is similar to that for Logical Errors Insertion. Flip-flops U14 and 21B form a three stage flip-flop which is clocked by data from the Sequence Generator. Violations are inserted by inhibiting the flip-flop U12 in the Bipolar converter circuit following the format decribed in Section 4.1.1. The Violations Circuit is signaled with a Zero Decoder output which has been synchronized to the transmitted data by the External Error Interface Circuit.

4.3.15 External Error Interface

This circuit accepts random APS Violations or External Errors Control Signals and synchronizes them to the Transmitter Clock and Transmitter Data.

Logical error synchronization to the Transmitter Clock is acheived by U17A and B. A positive transition of the external errors control sets the output of U17A. The next positive transition of the Transmitter Clock sets U17B and resets U17A. The output of U17B has a duration of one clock cycle and signals the logical error circuit to insert one error.

Violations synchronization to the transmitter data is achieved by U15A and B. Operation is identical to the logical errors circuit with the transmitter data used in place of the Clock.

4.4 RECEIVER CIRCUITS

4.4.1 Receiver Module (A3), Automatic Line Buildout (ALBO)

4.4.1.1 Loopback Control

Loopback between Transmitter and Receiver is controlled by a reed relay (K1) and its coil driver (Q20, 26). The loop is normally closed, and is opened by insertion of a plug into the DS1/DS1C INPUT jack or by holding the SELF TEST switch at its INTERRUPT DATA position. The relay is de-energized when the loop is open.

4.4.1.2 Automatic Line Build Out (ALBO) - Model 273A-1

The ALBO is essentially an adjustable attenuator whose amplitude and phase characteristics force its output signal (TP7) to look as if it were at the end of 4000 ft. of cable independent of the cable length terminated by the DS1/DS1C input. The amount of attenuation introduced is controlled by a DC level (TP6) from the AGC circuits.

The received bipolar data is transformer coupled (2:1 ratio) to a high input impedance FET follower Q28. An input impedance greater than 1000 ohms at the T1C rate is attained.

The output of the FET follower is capacitively coupled to the base of Q19, an emitter follower. Resistors R62, 64, 65 determine the quiescent operating point of this and subsequent stages.

Emitter follower Q19 drives the first of two attenuator sections. The first section consists of R59, R60, C32, L12. A DC blocking capacitor C33 connects Q25 and R70. Field effect transistor Q25 is operated in the resistive mode and is dependant on the control voltage from the AGC circuit. The combination of R70 and Q25 adjust the Loss/Phase characteristics of the section.

A Darlington connected transistor pair Q17 and Q18 provide an interface between the first and second attenuator sections. The second section is composed of R54 and L11. Capacitor C31 provides AC coupling to the dynamic resistance created by R82 and FET Q24. The FET operates in the resistive mode and is controlled by the AGC circuit. Emitter follower Q16 interfaces the ALBO with the equalizer.

4.4.1.3 Equalizer

The intent of the Equalizer is to remove the amplitude and phase distortion which would develop from transmitting a 3V bipolar signal down 4000 ft. of cable. Two filter sections and a gain stage accomplish this task.

Components R43, 45 and L7 determine the frequency response of the first section. Transistors Q15 and Q27 form a Darlington amplifier section. An emitter follower Q14 interfaces the first and second filter sections.

Components R40, 43, 39 C23, and L6 determine the frequency response of the second section. Transistors Q12 and Q13 provide a Darlington connected interface amplifier.

Final amplification is achieved with the Darlington pair Q10 and Q11. Voltage gain is set by the ratio of R34 and R35. Capacitor C22 provides an AC by pass for bias resistor R36.

4.4.1.4 Automatic Gain Control (AGC)

The AGC circuit monitors the output of the Equalizer and fowards a DC level to the ALBO which adjusts its attenuation to maintain the Equalizers output at approximately two volts peak. Major circuit components are a peak detector (Q21) and differential amplifier (Q22, Q23).

Transistor Q21 conducts each time the output of the Equalizer exceeds the voltage across C29 plus one diode drop. Therefore, the voltage across C29 represents the peak output of the Equalizer. Resistor R47 and C30 provide ripple filtration.

The voltage across C30 is compared to that of voltage divider R51, R52 by differential amplifier Q22, Q23. Overall AGC gain is determined by R49, selected during calibration.

4.4.1.5 Slicer

The Slicer combines two separate functions. First, it sets an amplitude threshold which recognizes "1" or "0" logic data levels. Second, it separates the positive and negative bipolar levels into two separate data signals which are TTL compatible.

The slicing amplitude threshold is set by the ratio of R31 and R30. Transistors Q6 and Q8 conduct only when their respective inputs from transformer T1 exceed this threshold. The transformer secondaries are connected such that the bipolar signal presented to these transistors is 180° out of phase. As a result, Q6 conducts for one polarity of the bipolar signal and Q8 for the opposite polarity. Transistor Q9, connected as a diode, offsets the effects of the base-emitter voltage drop of Q6 and Q8.

Transistors Q6 and Q8 drive switching transistors Q5 and Q7 respectively, which interface the Receiver with TTL logic levels.

4.4.2 Receive Module (A3) Variable Threshold

The main purpose of the Front End is to provide a high impedance (1K ohm at T1C) input to the incoming signal, and provide output signals to the slicer circuit (4.4.1.2) from which it can extract the positive and negative bipolar signals.

The input signal is transformer coupled (T1) to the gate of the input stage Q1. The transformer and FET combine to provide a high impedance. The output of the FET follower is capacitively coupled to the base of Q2, the gain of which is adjusted to 6 dB via select resistor R6 (nominally 2K ohm). This stage compensates for the loss through transformer T1.

Emitter follower Q3 is used to drive transformer T2 which splits the incoming bipolar waveform into two waveforms 180° out of phase. One

waveform consists of positive pulses for positive voltage 1's and the other consists of positive pulses for negative voltage 1's. These two signals are then feed to the slicer circuitry.

4.4.2.1 Slicer

The slicer combines two separate functions. First it sets an amplitude threshold which recognizes a "1" or "0" logic data level. Second, it separates the positive and negative bipolar levels into two separate data signals which are T^2L compatible.

Integrated Circuit (U2) consists of five matched transistors, two of which (Q3, Q4 with C8 and R20) form a peak detector which is used as a reference for detection of a logic "1". Transistors Q1 and Q2 present high impedance loads to the transformer outputs and low impedance outputs to comparator (U1). The fifth transistor Q5 is connected as a diode and is used to compensate for the Vbe loss across the other transistors. U1 consists of two comparator circuits, the negative input of each is tied together and to the peak detector's output. The positive inputs are feed from the two output pulse streams from U2 (Q1, Q2). The two outputs of this chip are now unipolar T^2L compatible levels one of which is from positive 1's and the other is from negative 1's. These lines (bipolar A and bipolar B) are used for clock extraction, and all waveform analysis done on the Receiver reference card.

4.4.3 Receiver Reference (A10)

4.4.3.1 Sampling Flip-Flops

Positive and negative data bits from the outputs of the slicer (receiver module) are channeled to the input of two D-type flip-flops (U4A and B respectively). Sampling is achieved by clocking these flip-flops with the receive data clock.

4.4.3.2 Bipolar/Unipolar Converter

Conversion to a unipolar NRZ (nonreturn-to zero) format is accomplished by ORing together the outputs of sampling flip-flops U4A and B. The OR function is provided by U3A.

4.4.3.3 Bipolar Violations Detector

This circuit consists of two- 2-stage binary counters (U5 and U6), A gate for each counter ANDs the Receiver Clock pulses with a Slicer output to give Return to Zero (RZ) signals which toggle and reset the counters.

When a 1 of positive polarity is received, the first stage of one counter is set and the second counter is cleared. If the next '1' received is also of positive polarity, another count will be added to the first counter, indicating the occurrence of a violation; however, if the next '1' had been of negative polarity, this counter would have cleared and a count of one would have registered in the first stage of the second counter.

ORing the two counter outputs and ANDing the result with the unipolar data stream completes the bipolar violations detection process. The resultant violations data is channeled to the Error Counter for subsequent display, provided the MODE switch is set for VIOLATIONS.

4.4.3.4 Clock Extractors

The Receiver derives clock pulses from incoming data, rather than from an internal clock, so that it can properly synchronize with incoming signals.

The outputs of the Slicer are OR-ed together by U2B and trigger the oneshoot multivibrator U12A. Constant width pulses produced by the multivibrator add energy to the tank circuits driven by transistors Q1 and Q2. Tank circuits C6, L1 and C9, L2 are tuned to 1.544 MHz (T1) and 3.152 MHz (T1C) respectively. Pulsing these HIGH-Q circuits causes them to ring at their respective frequencies. Each tank circuit drives a two transistor Darlington emitter follower (Q5, 3 and Q6, 4) followed by a phase shift circuit and slicer (U14). Finally, one of the two clocks is selected by the BIT RATE Switch (T1/T1C) working in conjunction with U15A.

4.4.3.5 NO DATA/LOST DATA Detector

These two circuits provide coverage of data loss from the instant of stoppage to the instant of manual resynchronization. The No Data Detector provides visual warning via the NO DATA indicator when data is not being presented to the Receiver. The Lost Data Detector shows loss of data via the LOST DATA indicator, which goes on with the return of data and remains on until the RESET/RESYNC switch is activated.

The No Data Detector, consisting of U8 monitors the output of the slicers through U2B. The dual retriggerable monostable multivibrator IC8 is connected in a tandem arrangement, where the second stage is triggered by an output of the first. The first stage is continuously retriggered by data pulses from the output of IC2B. In the event that data is interrupted, retriggering is discontinued, permitting this stage to complete its monostable function. The time constant of the first stage (26.5 microseconds) is determined by circuit elements R3 and C2. This time constant corresponds to 41 $\pm$ 9T1 time slots. An output from this stage is applied to the gate input of the first stage which inhibits triggering of the first stage for a 100 ms period following detection of No Data. The 100 ms time constant is determined by components R4 and C3. The output of the No Data circuit is extracted from the first stage. This output is directed to both the No Data indicator buffer through U1F and to the clock extractor circuit U2A. Flip-flop U16 controls the LOST DATA indicator. It is set whenever the NO DATA indicator goes off and is reset only by actuation of the RESET/RESYNC switch.

4.4.3.6 All 1's

The all 1's circuit identifies received data patterns which contain more than one hundred consecutive 1's and lights the Receiver Status All 1's indicator.

Three serially connected binary counters (U10, 11, 17) are permitted to count clock pulses whenever the unipolar data registers a "1". These counters are reset to zero for each occurance of a "0". If the data contains one hundred consecutive 1's, U17 overflows and sets flip-flop U9B. An output of U9B turns on the ALL 1's indicator through U13B. When a "0" in the data is detected U10, 11, 17, and 9B are immediately reset.

Flip-flop U9B triggers monostable multivibrator U12B which continues to hold the ALL 1's indicator on for another 100 ms. This delay provides sufficient time for the eye to detect the presence of all 1's patterns of only one hundred bit times (65 microsec, T1).

4.4.3.7 Strap Option A

This option allows the binary counters to accept up to one thousand and twenty-four (1024) consecutive 1's.

4.4.4 Receiver Logic (A5 Module)

4.4.4.1 Receiver Sequence Generator

The Receiver Sequence Generator produces a test sequence identical to that of its Transmitter counterpart. Its outputs are taken from different stages of the shift register, its timing is derived by extracting clock pulses from incoming data, and its feedback loop may be opened to receive incoming data for the purpose of synchronization with this data. Generator components are U1, 2, 3, 5; 10A serves as the exclusive-OR circuit in the feedback link. The bridge between stages 17 and 18 contains the Loop Control circuitry which opens or closes the feedback loop (U4).

With the feedback loop closed, the Receiver Generator behaves exactly as the Transmitter Generator in working up the 1,048,575 bit test sequence, but it is necessary to synchronize the test sequence from the Receiver Generator with that of an incoming signal if a bit-by-bit comparison of data bits is to be performed. This synchronization is achieved by opening the feedback loop and inserting the incoming signal in place of the Generator's output. The Generator responds as if the loop were closed, and within a very brief time interval (twenty data bits later), the Generator's output corresponds exactly with the data being inserted in its place.

Should incoming data contain error bits during synchronization, the process will be delayed. In order for synchronization to be achieved, incoming data must contain at least twenty error-free bits; an additional forty error-free bits must be received in order to confirm synchronization. Once synchronization is confirmed, the Generator's Sync Control circuit forces the feedback loop to its closed status so that normal operation may resume.

Should synchronization be lost during normal operation, the loss is detected by the Out-of Sync Detector. In the AUTO mode, this circuit then signals the Sync Control to reopen the feedback loop for resynchronization. Resynchronization in the MANUAL mode is initiated by actuating the RESET/RESYNC switch.

4.4.4.2 Loop Control

A gate system (U4A,B,C) effectively forms an SPDT switch which controls the Receiver Generator's feedback loop. The input to stage 18 from U4C is the common line. When the loop is closed, stage 18 receives data directly from the output of state 17; when the loop is open, it receives the incoming unipolar data signal. Should synchronization be required, the Sync Control may force the Loop Control to switch stage 18 to the incoming data line. If the Generator is properly synchronized to incoming data, there will be no signal from the Sync Control, and the Loop Control will, therefore, switch data from stage 17 to stage 18.

4.4.4.3 Receiver Zero Counters

Two zero counters are required to effectively control the Sequence Generator. One zero counter (U6, U9A) detects the presence of fourteen or more zeros at the third stage of the sequence generator. When operating at the T1 data rate, an output of flip-flop U9A signals the Invert Data circuit, limiting the number of consecutive zeros exiting the Sequence Generator to fourteen without disturbing the contents of the shift register.

A second zero counter (U32, 33) monitors the nineteenth stage of the Sequence Generator. This generator detects pattern lengths of nineteen and twenty zeros. The nineteen zero pattern defines the RECEIVER WORD SYNC pulse. Twenty or more zeros stimulates the Self Start Circuit.

4.4.4.4 Self-Start

Operation and function of this circuit (U8A) are identical to the Transmitter equivalent. Its input is taken from the Second Zero Counter and its output is routed to the Sequence Generator's 19th stage.

4.4.4.5 Zero Suppression Control

The Receiver Zero Suppression Control circuit operates in a manner similar to its Transmitter counterpart. The Sequence Generator is capable of producing a sequence of up to twenty 0's. To meet the required pattern specifications, it is necessary to limit 0 sequences to a maximum of fourteen by converting any additional 0's to 1's, when operating at the T1 Bit Rate. The control signal from U9A informs the Invert Data Gate (U10B) as to which of the output data bits are to be converted from 0's to 1's.

4.4.4.6 Comparison Gate

The Comparison Gate (U10C) is an exclusive-OR used to compare the received data stream from the Bipolar/Unipolar Converter with the test pattern from the Sequence Generator. Comparison is performed bit-by-bit, and any differences appear as logical 1's at the output of the Comparison Gate.

4.4.4.7 Violations/Errors Sampling

This circuitry samples detected violations and logical errors with the Receiver Clock to eliminate pulse transients which occur in the comparison logic. The MODE switch interacts with sampling flip-flops U11A and B to select either a logic or violations error mode. The outputs of these flip-flops are directed to NAND gate U12B through U12A. U12B combines the error signal and Receiver Clock to produce individual error pulses one-half bit time long. These errors are subsequently directed to the Error Counter.

4.4.4.8 Out of Sync Detector

The Out of Sync Detector monitors outputs from the Violations/Errors Sampling circuit, Error Counter and Bit Counter (Par. 4.4.3.8 and 4.4.3.9). When an out of sync condition is detected, a control signal is sent to the Loop Control which injects received data into the Sequence Generator. After a period of forty error free bits, synchronization is considered re-established and the loop is directed to close.

A two stage shift register (U16A and B) is clocked by an output of the Bit Counter which occurs every twenty bits. If the RESET/RESYNC switch is actuated, U16A and B are set by a short pulse generated by differentiator C6 and R10.

A set condition on U16B steers error pulses to the preset inputs of the shift register via U17A. After a period of twenty bit times, U16A becomes cleared when clocked by the Bit Counter. After another period of twenty bits, U16B is cleared when clocked provided an error has not occurred during the last twenty bits. A detection on one error during this time sets both shift register stages, starting the process over. An output from U16B illuminates the NO SYNC indicator through U13D. When Sync is restored, U15B is clocked, setting this flip-flop and illuminating the LOST SYNC indicator through U13C. Both indicators are held on by alternate inputs of U13C and D when the MODE switch is either in the VIOLATIONS or APS position. Flip-flop U15 is reset by actuating the RESET/RESYNC switch.

Loss of synchronization is determined by an interaction between the Error Counter and Bit Counter. The Error Counter counts detected errors and is reset by the Bit Counter, which counts clock cycles (Bit Slots). Both counters are operator programmable by strapping terminal pairs B1, A1, B2, A2. With no straps, the Error Counter will be reset after the passage of fourty bits. Straps A2 and B2 provide reset after 400 and 4000 bits. Similarly, the Error Counter will overflow after the passage of twelve errors with no straps. Setting straps A1 and B1 provide error counts of 120 and 1200. The unit is shipped from the factory with no straps. Therefore, after the passage of 40 bits, the Error Counter will be reset. However, if more than twelve errors occur within 40 bits, the Error Counter will overflow signalling an out of sync condition having a threshold of twelve errors in fourty bits. The strap options provide thresholds of: 12 in 400 or 4000, 120 in 400 or 4000 and 1200 in 4000.

When overflow occurs, the Error Counter signals U18A which sets the shift register (U16A and B). If the SYNC MODE switch is set to the AUTO position, the Loop Control will again insert received data into the Sequence Generator and the process described for the RESET/RESYNC switch earlier will commence. However, if the MANUAL position is chosen, an auxilliary input to U17D will prevent the Loop Control from inserting received data and a NO SYNC condition will prevail until operation of the RESET/RESYNC switch.

4.4.4.9 Error Counter

The Error Counter consists of three decade counters (U21, 22, 23), a flip-flop (U19) and decoded gates. Errors from the Violations/Errors sampling circuit are counted with reset provided by a pulse from the Bit Counter. Decoding logic determine error counts at 12, 120, 1200 levels. U27A combines outputs of U21 and 22 to produce a pulse every 12 errors. Gates U27B and U28A decode 120 and 1200 counts respectively. These decoded outputs are combined by U27C and inverter by U28B which provides an overflow signal to the OUT OF SYNC Detector.

With out straps, decoder U27A (Decode 12) occurs prior to outputs of U27B and U28A. This is, therefore, the dominant decoder. If strap A1 is asserted, U27A is inhibited and U27B (Decode 120) becomes dominant. Further, if straps A1 and B1 are asserted, decoder 28A becomes dominent (Decode 1200).

4.4.4.10 Bit Counter

The Bit Counter is essentially a programmable decade counter which outputs a clock to the OUT OF SYNC Detector every twenty bits and a reset signal to the Error Counter every 40, 400 or 4000 bits as programmed by straps A2 and B2.

Decade Counter U24 and flip-flop U20A divide the Receiver Clock by twenty. This provides Clock for the OUT OF SYNC Detector. Outputs from Flip-flop U20B, decade counters U25 and U26 continue the divider chain to 40, 400 and 4000 bits. Steering logic, U30A,B,C and U31A, B work in conjunction with straps A2 and B2 to select one of these three outputs. No straps select the 40 bit output. Strap A2 selects 400 and strap A2 plus B2 selects 4000 bits. Flip-flops U29A and B with gates U28B and C generate a reset signal at the end of the selected bit interval which resets U25, U26, U20B and the Error Counter. A preset input to flip-flop U29A, asserted when the Error Counter overflows, forces an early reset signal coincident with the detection of an out of sync condition. This process helps to reduce the number of bit times required to recognize and re-establish synchronization.

4.4.5 Display Logic Module (A8)

4.4.5.1 Error Format

The Error Format circuit accepts detected individual errors (Logical or Violations) and converts them to error sec., error decisec and 0.3 ms blank formats as selected by the DISPLAY FORMAT switch. The errors sec. mode establishes consecutive blocks of data one second long. One or more errors detected in a block is converted to a single error pulse which will be subsequently counted by the Display Error Counter. Error Deci-Sec. is identical to Error Sec except the data blocks are 0.1 sec long. In the .3 MS BLANK mode, the circuitry waits for the detection of an Error and then inhibits (blanks) the Display Error Counter from counting errors for a period of 0.3 ms after this first error is registered. The Individual mode permits counting of all errors as they are detected.

Detected errors are directed to one input of NAND gate U13A. This gate permits errors to pass only during a count interval. The output is inverted and applied to the clock input of U15A. When the individual mode is selected, the "D" input to this flip-flop is held low resulting in a Hi output from U15A irrespective of the number of errors presented to the clock input. U12C functions to combine the output of U15A and U13A. With the output of U15A high, all errors gated by U13A are passed to the Display Counter.

With the DISPLAY FORMAT switch set to ERROR SEC, errors at the clock input of flip-flop U15A set the output low. This action prohibits U12C from passing individual errors to the Display Counter and removes the reset applied to oscillator U14. The oscillator produces a clock rate of ten cycles per sec. which is divided by ten with decade counter U16. Steering logic U17 directs the output of counter U16 to the differentiator U18A,B,C and C18. This circuit produces a narrow negative transition pulse for each negative transition of U17A. The output of flip-flop U15A is thus cleared after a period of one second producing one error pulse for one or more errors in a one second block. Under error free conditions, U15A is simply reset every second. But, since it was not set by an error, no error pulse is generated.

Operation in the Deci-Sec mode is identical to that in the Sec mode except U17A chooses the oscillator output (0.1 Sec) rather than the divided output (1.0 Sec) of U16.

When switched to the 0.3 ms Blank mode, the oscillator U14 is adjusted to generate a clock of 0.3 ms period. Resistors R34, R35, R36 and capacitor C14 determines the 0.3 ms rate. The switch is made by turning on Transistor Q1 which places R33, 32 in parallel with R34, R35, reducing the circuits time constant. Reset of flip-flop U15A is now determined by the 0.3 ms rate. However, reset does not occur continuously. One input of U13D is now held high by the DISPLAY FORMAT switch and inverter U13C. When U15A is reset, oscillator U14 is also held in reset. An error sets U15A and removes the reset on U14 allowing it to complete a 0.3 ms cycle. This, in turn, resets U15A after 0.3 ms. Errors occurring during this period are blocked by U12 and associated output of U15A. The result is one error pulse for one or more errors during the 0.3 ms period.

4.4.5.2 Display Multiplexer Control

The Display is multiplexed by digit (most significant, MSD, to least significant, LSD), and by function (error count or timer status).

The digit mux. rate is determined by oscillator U1 in conjunction with R1, 2 and C2 which set the time constant. Inverter U5A connects the oscillator with Johnson Counter U2A, B. Outputs of the counter are decoded by U3A, B, C, D. These outputs are connected to the DISPLAY Module to scan the three digits sequentially and reset the leading zero suppression control.

When the Test Set is operated in the APS mode, the Counter U2 is held reset by U32. This effectively blanks the three digit display.

A common BCD data bus (wire OR-ed) connects the three digits of the Error Display Counter and Timer Counter with the Display Module. Selection of the Timer Counter (TIMER STATUS) is determined by gate logic U5B, C, D. Similar circuits on the BUFFER/APS module select the Error Display Counter. The TIMER STATUS switch determines which function is to be displayed.

4.4.5.3 Timer Counter

The Timer consists of three presettable decade counters U6, 8, 10. These counters are preset by BCD data (complement, $\overline{BCD}$) from the TIMER thumbwheel switches when the RESET/RESYNC switch is operated. A clock having a period of one minute forces the counters to count down from their preset value to zero. The zero condition signals the Count Control to end the Count Interval. The status of the Timer (test time remaining) can be displayed by operating the TIMER STATUS switch. Open collector gates U7, U9, U11 in conjunction with signals from the Display Mux. control place the Timer Counter outputs on the Data Bus (MSD to LSD).

4.4.5.4 Bit/Time Interval Control

The Bit/Time Interval Control determines the test length (count interval) in either bits (10^6, 10^7, 10^8, 10^9) continuous, or TIMER (1 to 999 minutes) as selected by the COUNT INTERVAL (Bits) switch. Bit rates are determined by the Receiver Word Sync signal which is generated every 1,048,575 bits (10^6).

Three decade counters U23, 24, 25 and selection logic U20A, B, C, U21B determine the bit rates: 10^6, 10^7, 10^8, 10^9.

The one minute clock pulses required by the Timer Counter are derived from the Word Sync signal by forcing counters U23, 24, 25 to divide by 88 for T1 and 180 for T1C bit rates. U26A decodes 88 if the BIT RATE switch is set to T1 while U26B decodes 180. Flip-flop U28 produces a pulse, one Receiver Clcok period in width, every 88 or 180 Word Sync cycles. If a count interval is in process, U27C directs one minute clock pulses to the Timer Counter through inverter U27D and resets U23, 24, 25 through U27B.

Gates U20A, B, C, D, U21B, C, U19A, B, C direct appropriately selected bit rate or timer, count interval completed, signals to the Count Control circuits.

4.4.5.5 Display Interval

The length of time (1 - 10 sec and hold) that the final results of a completed counter interval are displayed before testing is restarted is determined by this control. A monostable oscillator U30 in conjunction with the DISPLAY INTERVAL CONTROL, R37, 38 and C11 determine display time.

The hold feature is executed by turning transistor Q2 on which restricts capacitor C11 from charging. Completion of a Display Interval signals the Count Control to start another count interval.

CHART 1

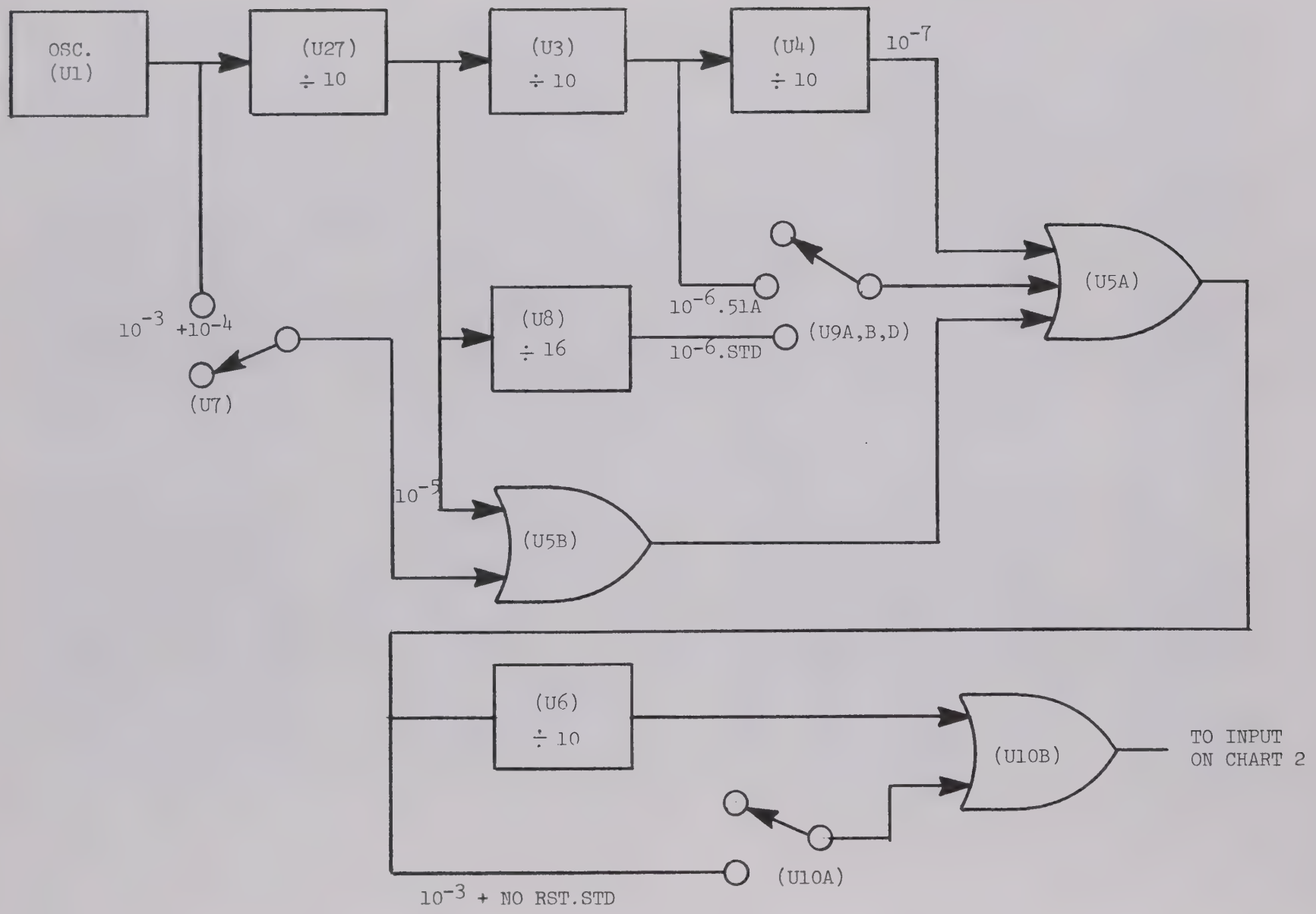
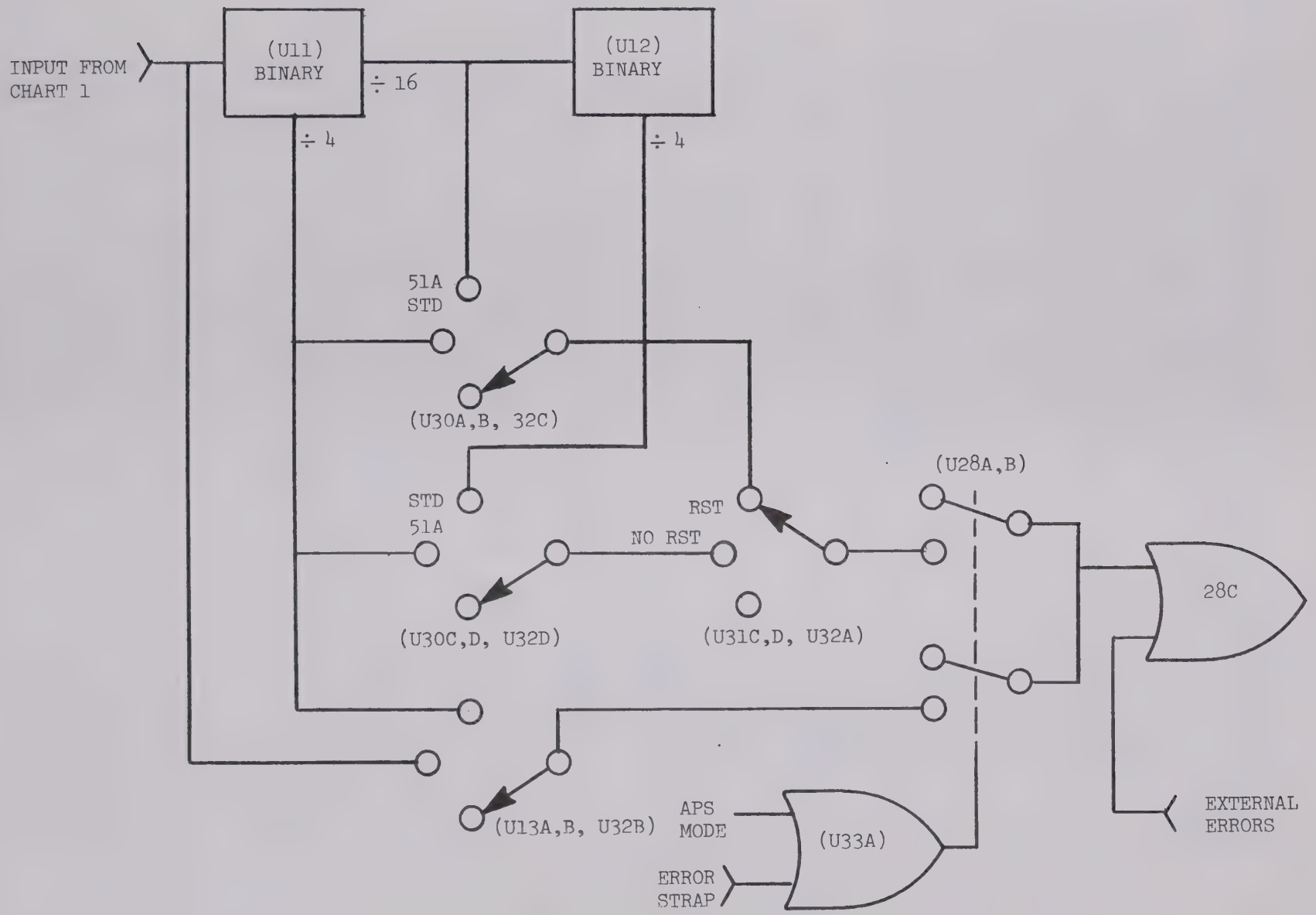

OSC.
(U1)
(U27)
÷ 10
(U3)
÷ 10
(U4)
÷ 10
10-7
10-3 +10-4
(U7)
(U8)
÷ 16
10-6.51A
10-6.STD
(U9A,B,D)
(U5A)
10-5
(U5B)
(U6)
÷ 10
(U10B)
TO INPUT
ON CHART 2
(U10A)
10-3 + NO RST.STD

CHART 2


INPUT FROM CHART 1
(U11) BINARY
÷ 16
(U12) BINARY
÷ 4
÷ 4
51A STD
(U30A,B, 32C)
STD 51A
RST
NO RST
(U28A,B)
28C
(U30C,D, U32D)
(U31C,D, U32A)
(U13A,B, U32B)
APS MODE
ERROR STRAP
(U33A)
EXTERNAL ERRORS

4.4.5.6 Count Control

The Count Control issued signals to other circuits which determine the test length (count interval).

Flip-flop U31A is cleared by a signal from the Display interval control when clocked by the Word Sync signal. This action creates a reset signal which resets the Error Display Counter and loads the Timer Counter. The next occurence of the Word Sync signal clears flip-flop U15B and starts the count interval. The negative transition of the Word Sync clears U31B which in turn sets U31A removing the reset signal. U15B is clocked by an output of the BIT/TIME interval control which terminates the count interval, provided the COUNT INTERVAL (Bits) switch is not set to CONT (continuous). This condition holds the D input of flip-flop U15B low, preventing it from setting. An output from U15B is directed to Q2 of the Display Interval circuit to stimulate the beginning of another count interval through U12D. An auxilliary input to U12D inhibits this process when the COUNT INTERVAL (Bits) switch is set to TIMER. This effectively holds the Display regardless of the DISPLAY INTERVAL control's position.

4.4.6 BUFFER/APS MODULE (A7)

4.4.6.1 APS Violations Control

The APS VIOLATIONS CONTROL determines the violation insertion rate when the Test Set is operated in the APS mode. An output from this circuit stimulates violations control circuits on the Transmitter module. RANGE, SEQUENCE and STD/51A front panel switches determine the rate of violation insertion.

Oscillator U1 generates a 3081 Hz square wave which acts as a time base for an elaborate divider scheme. The circuit time constant is dependent on R5, 6, 7 and C22. At the time of this writing, automatic protection switches were not available for T1C channels. In anticipation for future expantion to T1C, transistor circuit Q1 has been added, which places R2, 4 in parallel with R5, 6 to adjust the circuit time constant.

The following two charts present a flow graph of the divider. Items in parentheses depict integrated circuits to perform the particular function illustrated. Numbers 10^{-3}, 10^{-4} etc. identify signal paths corresponding to RANGE switch positions. Other identification corresponds to SEQUENCE and 51A/STD switch positions. Charts have been chosen to simplify an otherwise lengthly written description.

4.4.6.2 Error Display Counter

The Error Display Counter tallies errors presented to it from the Error Format circuit. Counter outputs are multiplexed and placed on a data bus which interconnects the Error Display Counter, Timer Counter and Display.

A three digit BCD counter is formed using decade counters U17, U19, U21. Outputs of these counters are multiplexed by open collector NAND gates U18, U20, U22 in a wire-OR configuration. Multiplex control signals are steered to these gates by U14A, B, C and inverter U15. Transfer of these outputs to the bus is inhibited when the TIMER STATUS switch is operated.

4.4.6.3 Strap Options

The Transmitter Module can be forced to transmit an ALL 1's pattern by applying a strap between terminals "C" or grounding Pin 43 on the INTERFACE CONNECTOR (option P, Par. 4.4.5.4).

Strap option "B" modifies the transmitter and receiver Sequence Generators to produce patterns limited to fourteen zeros at both the T1 and T1C bit rates. The Test Set is manufactured without this strap which provides fourteen zero suppression at T1 and no suppression at T1C (up to nineteen consecutive zeros).

Violation error rates generated by the APS circuits are normally available only with the MODE switch in the APS position. This lock out feature prevents accidental error insertion should the SEQUENCE switch be in a position other than START. However, some operators may find these error rates useful for other testing in the VIOLATIONS or LOGIC mode. A strap option has been provided (strap A or Pin 48 on INTERFACE CONNECTOR) which will override this lock out feature.

4.4.6.4 Printer/Remote Interface (Option P)

This interface permits the connection of a printer to the 273 and remote operation of some front panel controls. Connection to the printer is established through three parallel BCD data paths, one path for each digit of the Display Error Counter. The BCD is available at twelve pins of the Interface connector in complement BCD format, TTL levels.

Outputs of the Error Display Counter U17, U19, U21 are buffered and inverted by U23 and 24. A carry signal (10 ms pulse) is generated by U27 each time the most significant counter (U21) overflows. The print command (100 ms pulse) is generated at the end of each count interval. (Ref. Par. 3.2)

4.4.7 Display Module (A1)

The DISPLAY MODULE contains the three seven segment LED Displays, the Receive Status Indicators, RESET/RESYNC switch and TIMER STATUS switch.

Digit drivers (Q1, Q2, Q3) interface with display multiplexing signals from the DISPLAY LOGIC module to scan the Display from the most significant

digit (MSD) U5 to least significant digit (LSD) U7. Display decoder U3 converts the BCD input from the data bus to drive the seven segment LED displays. Resistors R7 through R13 determine the peak segment current.

Flip-flop U4 controls the Display's leading zero blanking. The flip-flop is cleared during a time slot between display of the LSD and MSD digits. An output from decoder U3 holds U4 in its cleared state, if the BCD data for the MSD is zero. Flip-flop U4 signals U3 to blank the Display. If the next digit is non-zero, U4 is set and removes the blank signal from U3. When the Test Set is operated in the APS mode flip-flop U4 is held in the clear state. The COUNT and OVERFLOW indicators are driven by transistors Q4 and Q5. Transistor Q5 is controlled by the same multiplexer signal which clears U4. Therefore, in the APS mode the COUNT and OVERFLOW indicators are held off.

Drivers U1 and U2 provide a buffer between Receiver Status indicators DS1 through DS8 and their respective control logic.

4.4.8 Power Supply Assembly (A6)

The Power Supply for the Test Set is composed of transformer T1, capacitor C1 (both chassis mounted), and Power Supply Assembly (A6). The transformer secondary is center-tapped and drives the full wave rectifier, CR1 and CR2. This Rectifier in conjunction with capacitor C1 provides 48 V DC. The Test Set can be powered by either 115 V AC, using transformer T1, or 48 V DC from an external power source (e.i. telephone central office battery: T1P, -48 V; sleeve, + ground). Diode CR3 interfaces the externally applied 48 V DC power with the internal 48 V DC power derived from the 115 V AC input.

A DC-DC converter consisting of transformer T2, Transistors Q1 and Q2, and bridge rectifier CR5, 6, 7, 8 converts the 48 V DC power to plus and minus 12 V DC. Capacitor C6 is the +12 V DC ripple filter and C7 the -12 V DC filter.

Four linear regulators determine the final power requirements of the Test Set, VR1, 2, 3, 4. Each regulator provides: +6.8 at 50 ma (VR1), +5 V at 1.2 ma (VR2), +5 V adjustable at 250 ma (VR3), and -5 V at 100 ma (VR4). The +5 V power supply (VR2) is overvoltage protected by zener diode CR9.

The Lost Power Circuit consists of detector U1 and reset circuitry Q3 and CR10. Detector U1 is established in the Set "1" state when power is first applied or interrupted for more than one second. In the set state, the lost power indicator is turned on. Reset is accomplished with the operation of the RESET/RESYNC switch and level shifter Q3.

SECTION 5

5.0 MAINTENANCE

5.1 Test Equipment Requirements

a. Frequency Counter — GR Model 1191 or equivalent

b. Osicilloscope — Tektronix Model 547 or equivalent

c. Oscilloscope Accessories — Tektronix Model 1A1 Plug-In or equivalent, with 2 each X10 Probes and 1 each X1 Probe (calibrate these items to be compatible with the Oscilloscope to be used).

d. Bell System J98710R T-1 Quasi-Random Signal Source or Bowmar 273A, 271A B, or C Error Rate Test Set.

e. Tapped Termination, 1 each per Figure 5-1.

f. Termination, 3 each, per Figure 5-2.

g. Resistor, 100 ohms, 1% with an alligator clip at each end.

h. Standard Error Rate Test set. This set must first have been qualified for use as an operating standard by (1) successfully passing Self Test requirements of Section 2.2, and (2) be certified as having synchronized to a Bell System J98710R T-1 Quasi Random Signal Source without recording errors (3) be certified to insert and detect both errors and violations exclusive of one another.

i. Storage Oscilloscope — Tektronix Model 549 or equivalent with a 1A1 Plug In.

j. D.C. Power Supply — Power Designs Model TW5005 or equivalent.

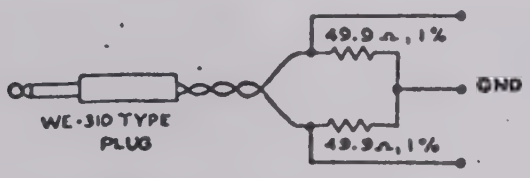


Fig. 5-1: Tapped Termination (1 Required)

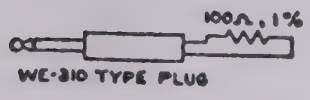


Fig. 5-2: Termination (3 Required)

5.2 Calibration Procedure

5.2.1 Preliminary

(a) Remove the Test Set from its outer case.

CAUTION: Voltages as high as 115 Vac are present in the vicinity of the Power Switch and the Fuseholder.

(b) Apply 115 Vac power to the Test Set and turn on the Power Switch.

(c) Do not connect equipment to the Test Set except as directed below.

5.2.2 Oscillator Frequency Adjustment

(To be made only after a one hour minimum warm-up)

(a) Connect the Frequency Counter to the TRANSMIT BIT SYNC and GRD terminals on the front panel of the Test Set. Set the BIT RATE switch to T1C.

(b) Adjust the counter for a one second count.

(c) Adjust capacitor C14, at the edge of the Transmitter board (A4) for a frequency of 3,152,000 Hz ± 5 Hz.

(d) Set the BIT RATE switch to T1.

(e) Adjust capacitor C18, at the edge of the Transmitter board (A4) for a frequency of 1,544,000 Hz ± 5 Hz.

(f) Disconnect the counter.

5.2.3 Transmitter Amplitude Adjustment

(a) Properly calibrate the Oscilloscope, Plug-In, and X10 Probe with respect to both frequency and amplitude using the internal calibration source.

(b) Plug the test termination shown in Figure 5-1 into one of the four output jacks of the Test Set and set the BIT RATE switch to T1.

(c) Connect an X10 Oscilloscope probe between the GRD terminal and either one of the remaining terminals of the Tapped Termination (Fig. 5-1).

(d) Set the Oscilloscope sweep for 0.1 usec/cm and vertical sensitivity for 0.05V/cm. Adjust potentiometer R6 (+5V Adjust), on the lower edge of the Power Supply board, for a pulse height of 1.5V (3 cm) ± 0.1V peak or 3.0V (6 cm) ± 0.2V peak as shown in Figure 5-3.

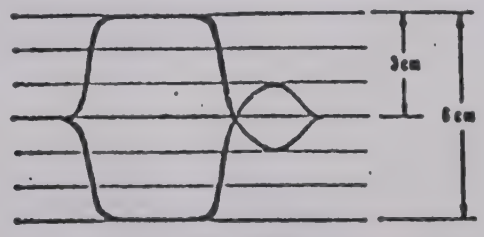


Figure 5-3: Transmitter Amplitude

(e) Disconnect the Oscilloscope Probe and unplug the test termination from the Transmitter output jack.

5.2.4 Receiver AGC (273A-1 ALBO)

This adjustment is not part of normal maintenance and should be necessary only when repair (component change) is required.

Resistor R49, on the Receiver Module (A3), is a select value determined by Bowmar during factory calibration. This resistor determines the voltage gain of the AGC circuit.

(a) Test Equipment Adjustments

273 Controls:

DISPLAY FORMAT	Individual
BIT INTERVAL	10^{-6}
MODE	Logic
BIT RATE	T1
BRIDGE/TERM	Term

Remove all DS1/DS1C 310 jack inputs and outputs.

Oscilloscope

CH1	X1 Probe, connected to TP7 (ALBO output), amplifier to 50mv/cm.
CH2	X10 Probe, connected to RECEIVER BIT SYNC on front panel, amplifier to 5V/cm.
Time Base	Trigger CH2, 0.5 us/cm.

(b) Temporarily connect R49, a 8.6K 5% 1/4W carbon composition resistor, to terminals provided.

(c) The waveform on CH1 (TP7) should be approximately 100 mv peak (finer adjustment to follow).

(d) Connect the Oscilloscope's CH1 to TP5 (equalizer output) and adjust CH1 amplitude for 1V/cm. Set the Test Set's BIT RATE switch to T1C.

Observe that there is a slight amplitude imbalance between the positive and negative pulses. Select the pulse of smaller amplitude and adjust R49 for a peak voltage of 2.2V $\pm$ .1V measured between the base line and the inner open section of the pulse (Fig. 5-4).

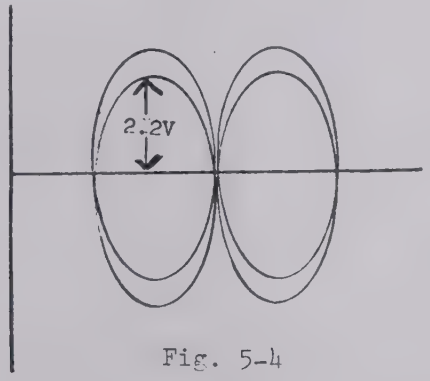


Fig. 5-4

(e) Solder R49 in place. Disconnect all test equipment

5.2.5 Clock Extractor Adjustments

(a) Test Equipment Adjustments

273 Controls	
BIT INTERVAL	10^{-6}
MODE	Logic
BIT RATE	T1
BRIDGE/TERM	Bridge
DISPLAY FORMAT	Single
Oscilloscope	
CH1	X10 Probe to TP2 amplifier to 2V/cm
Time Base	Set to 0.1 us/cm, EXT. SYNC. Connect a X1 Probe between EXT. SYNC. and Xmit BIT SYNC pin jack on front panel

(b) Use a tuning tool to adjust inductor L1 for a symmetrical square wave with clean transitions.

(c) Switch the sweep magnifier to X10 and adjust the Oscilloscope's position controls to bring the positive pulse transition into view (Fig. 5-5).

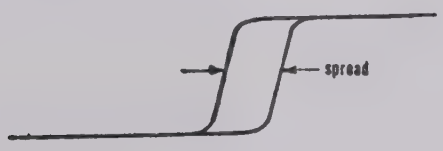


Fig. 5-5

(d) Continue to adjust L1 for a minimum spread on the transition edge, using the Oscilloscope's position controls to keep the pattern centered or conviently located.

(e) Place the 273's BIT RATE switch to T1C and connect the Oscilloscope's CH1 to TP1. Adjust L2 by repeating Steps b, c, and d.

(f) Remove Oscilloscope Probes from test points.

5.2.6 Clock Extractor Phase Adjustment

(a) Test Equipment Adjustments

Oscilloscope

CH1	X10 Probe connected to TP5, amplifier 2V/cm.
CH2	X10 Probe connected to TP3 (U4 Pin 3), amplifier 2V/cm.
Time Base	Adjust for 0.1us/cm and Synce to CH2.

(b) Adjust the Oscilloscope's horizontal position control to set the positive transition of CH1 on the vertical center line (See Fig. 5-6).

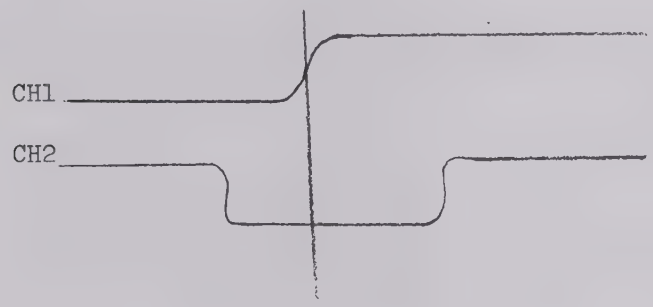


Fig. 5-6

(c) Adjust capacitor C11 to position the CH2 pulse symmetrically around the transition of CH1.

(d) Adjust the 273's BIT RATE switch to T1C.

(e) Adjust C12, following the procedure outlined in Steps b and c.

(f) Disconnect the Oscilloscope.

5.2.7 APS Violations Oscillator

(a) Connect a Frequency counter to TP1 of the Buffer/APS (A7) Board and set the BIT RATE Swtich to T1.

(b) Adjust R5 for a frequency measurement of 3081 Hz $\pm$ 5 Hz.

(c) Set the BIT RATE switch to T1C and adjust R2 for a frequency of 6290 $\pm$ 10 Hz.

5.2.8 Display Format Oscillator

(a) Connect a frequency counter to TP5 on the DISPLAY LOGIC (A8) board. Set the DISPLAY FORMAT switch to INDIVIDUAL.

(b) Set the counter's controls to make a period measurement (100 ms).

(c) Adjust R35 for a period measurement of 100 ms ± 1 ms.

(d) Connect a temporary jumper between ground (edge of card) and TP6.

(e) Adjust R33 for a period of 0.300 ms ± .001 ms.

5.2.9 Final

(a) Return the test set to its case and secure with the four front panel screws.

(b) Perform the Self Test (Section 2) as a final check of the instrument.

5.3 Performance Checks

5.3.1 Preliminary

These checks are to be made with the Test Set in its case. They may serve for periodic maintenance, quality control checks, and for post-repair checkout. The Error Rate Test Set must be connected to a power source of 115 VAC ± 10%, 50 to 60 Hz.

5.3.2 Transmitter Checks

5.3.2.1 Transmitter Clock Frequency

(a) Allow the Test Set to temperature stabilize by operating for at least one hour at room temperature. The Test Set may be momentarily unplugged only for the purpose of moving it.

(b) Connect the Counter input to the TRANSMITTER BIT SYNC jack and the GRD terminal located in the lower left section of the front panel. Set the BIT RATE switch to T1.

(c) Adjust the Counter for a one-second count interval (to read directly in Hz), and set the Counter's input control for a consistent display. The Counter should register between 1,543,950 and 1,544,050 at the end of each count interval.

(d) Set the BIT RATE switch to T1C. The Counter should register between 3,151,950 and 3,152,050 at the end of each count interval.

(e) Disconnect the Counter.

5.3.2.2 Bipolar Output (T1)

(a) Check calibration of the Oscilloscope and a X10 Probe with respect to frequency compensation and gain, using the internal calibration source of the Oscilloscope and the Oscilloscope manufacturer's procedure.

(b) Connect the cord of the test circuit shown in Figure 5-1 to one of the DS1 Output jacks of the Test Set, and insert the three Terminations (Fig. 5-2) into the remaining output jacks. Attach the GRD lead of the X10 Probe to the GRD, center tap of the test circuit and the Probe tip to either of the outer taps.

(c) Adjust the Oscilloscope for a vertical sensitivity of 0.05V/division and a sweep-rate of 0.1 usec/division (magnifier off). Adjust the trigger, intensity, and position controls to obtain the waveform shown in Figure 5-7.

(d) The measurements designated (1) and (2) in Figure 5-7 should be beteeen 2.7 and 3.3 cm (1.35 and 1.65 volts). Measurements (1) and (2) should differ by not more than 0.15 cm (0.075 volts.).

(e) Measurements (3) and (4) should be between 3.0 and 3.5 cm (300 and 350 nsec). Measurements (3) and (4) should differ by not more than 0.15 cm (15 nsec).

(f) Measurements (5) and (6) , taken between 10% and 90% of peak points, should be less than 0.8 cm (80 nsec).

(g) Measurement (7) should be between 10% and 30% of the base line to peak reading (norminally 0.3 to 0.9 cm for a 3.0 cm peak).

(h) Measurement (8) , taken 4.0 cm to the right of the point of measurement (7) , should be less than 10% of measurement (7) (Note: It may be necessary to increase the vertical sensitivity in order to make this measurement).

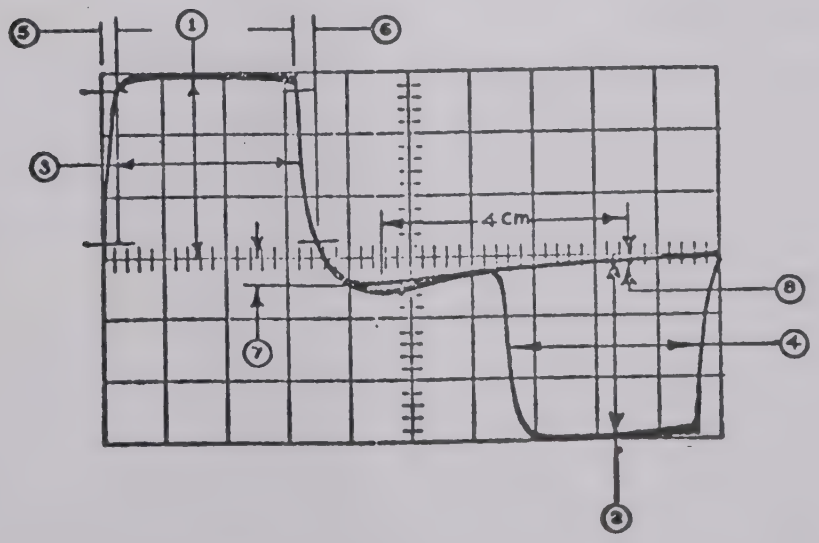


Fig. 5-7: Bipolar Waveform

(i) Exchange output jack connections with the Tapped Termination and one of the three other Terminations. Repeat Steps d through h, above.

(j) Repeat Step i, using a new output jack for the Tapped Termination.

(k) Repeat Step j. The Tapped Termination should now have been used in all four output jacks.

(l) Remove the three terminations one at a time observing the Oscilloscope trace. The trace should not be altered as the terminations are removed. Finally, move the Tapped Termination to one of the three other output jacks. The waveform of Figure 5-7 should reappear on on the Oscilloscope.

5.3.2.3 Bipolar Output (T1C)

(a) Set the BIT RATE switch to T1C, and insert the tapped termination into one of the DS1/DS1C outputs.

(b) Adjust the Oscilloscope for 0.5V/cm and .05us/cm.

(c) The measurements designated (1) and (2) in Fig. 5-7 should be between 2.7 and 3.3 cm (1.35 and 1.65 volts). Measurement (1) and (2) should differ by not more than 0.15 cm (0.775 volts).

(d) Measurements (3) and (4) should be between 2.9 cm and 3.5 (145 and 175 nsec). These measurements should not differ by more than .3 cm (15 nsec).

(e) Measurements (5) and (6) taken between 10% and 90% of peak points, should be less than .8 cm (40 nsec).

(f) Measurement (7) should not exceed 10% of the peak amplitude .3 cm. CAUTION: Poor Probe grounding will greatly effect this measurement.

5.3.3 Receiver Checks

5.3.3.1 General Functional Check

(a) Perform the complete Self Test Procedure (See Section 2).

DIAGRAMS

In Order of Presentation

Display Module (A1) Schematic D273-100
Display Module (A1) Assembly C273-200

Interconnect Module (A2) Schematic E273-101
Interconnect Module (A2) Assembly C273-201

Receiver Module (A3) Variable Threshold Schematic C273-109
Receiver Module (A3) Variable Threshold Assembly C273-209

Receiver Module, Option (A3) ALBO Schematic D273-102
Receiver Module, Option (A3) ALBO Assembly C273-202

Transmitter Module (A4) Schematic D273-103 sheets 1 and 2
Transmitter Module (A4) Assembly C273-203

Receiver Logic Module (A5) Schematic D273-104
Receiver Logic Module (A5) Assembly C273-204

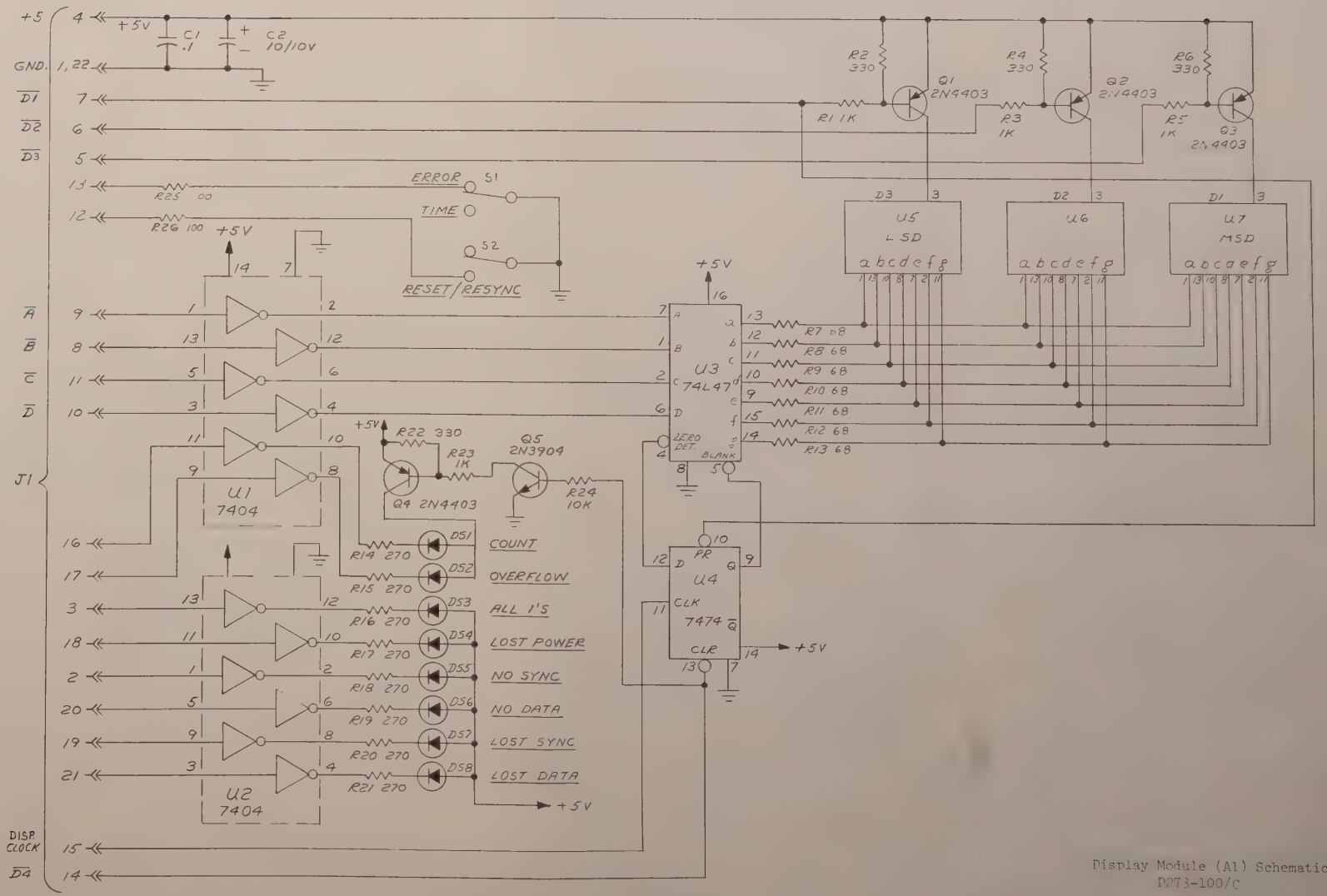
Power Supply Module (A6) Schematic C273-105
Power Supply Module (A6) Assembly D273-205

Buffer/APS Module (A7) Schematic D273-106 sheets 1 and 2
Buffer/APS Module (A7) Assembly C273-206

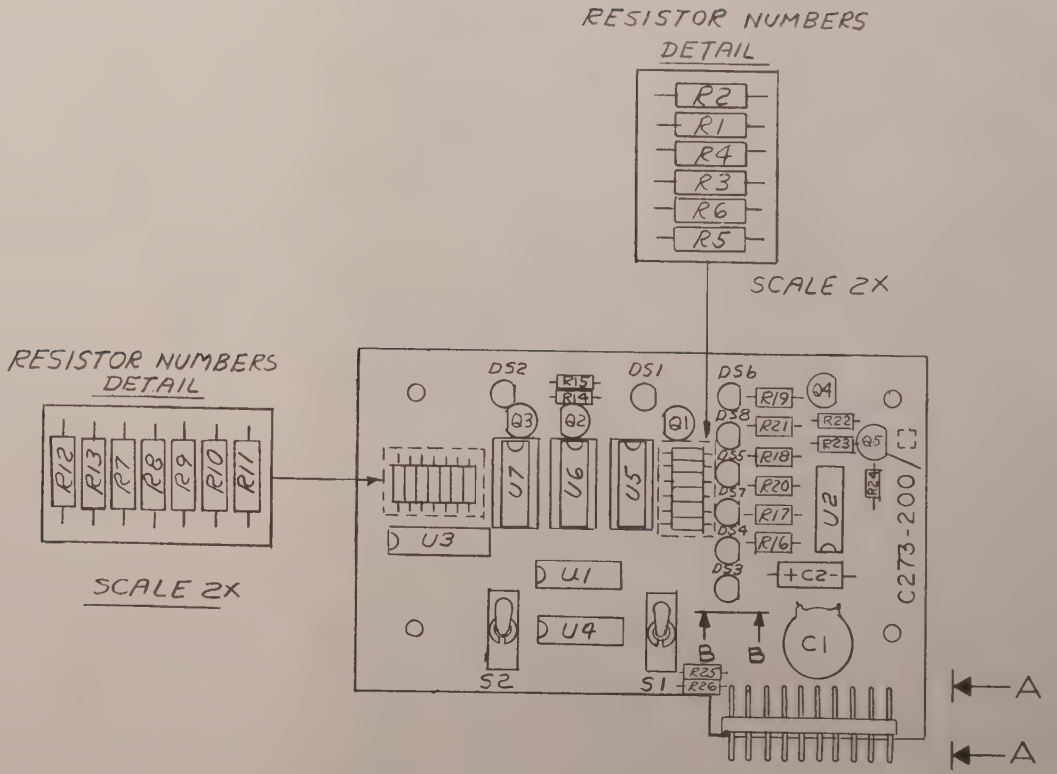
Display Logic (A8) Schematic D273-107
Display Logic (A8) Assembly C273-207

Receiver Reference Module (A10) Schematic D273-110
Receiver Reference Module (A10) Assembly D273-210

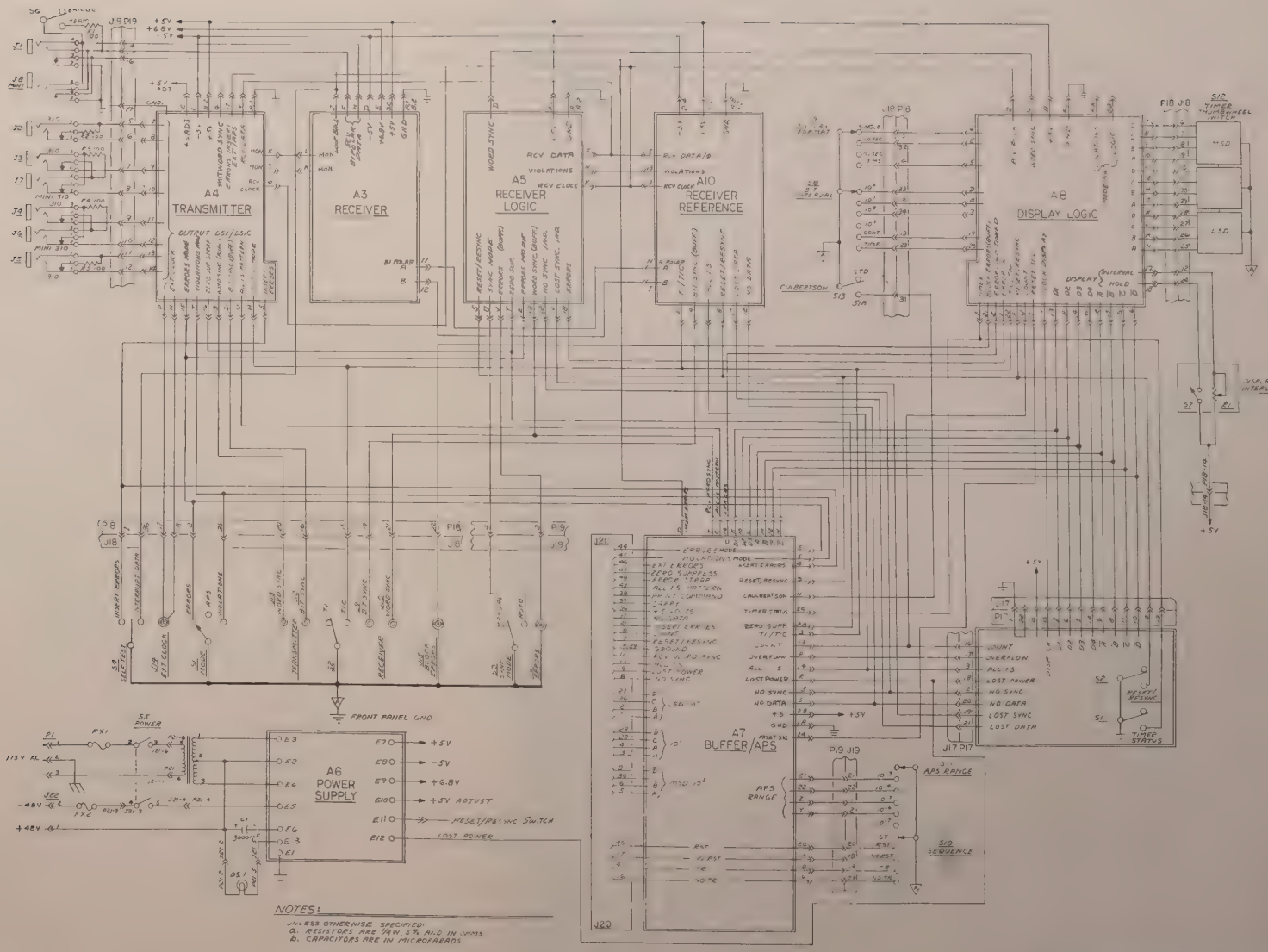
Digital Carrier Analysis Test Set Assembly E273-001



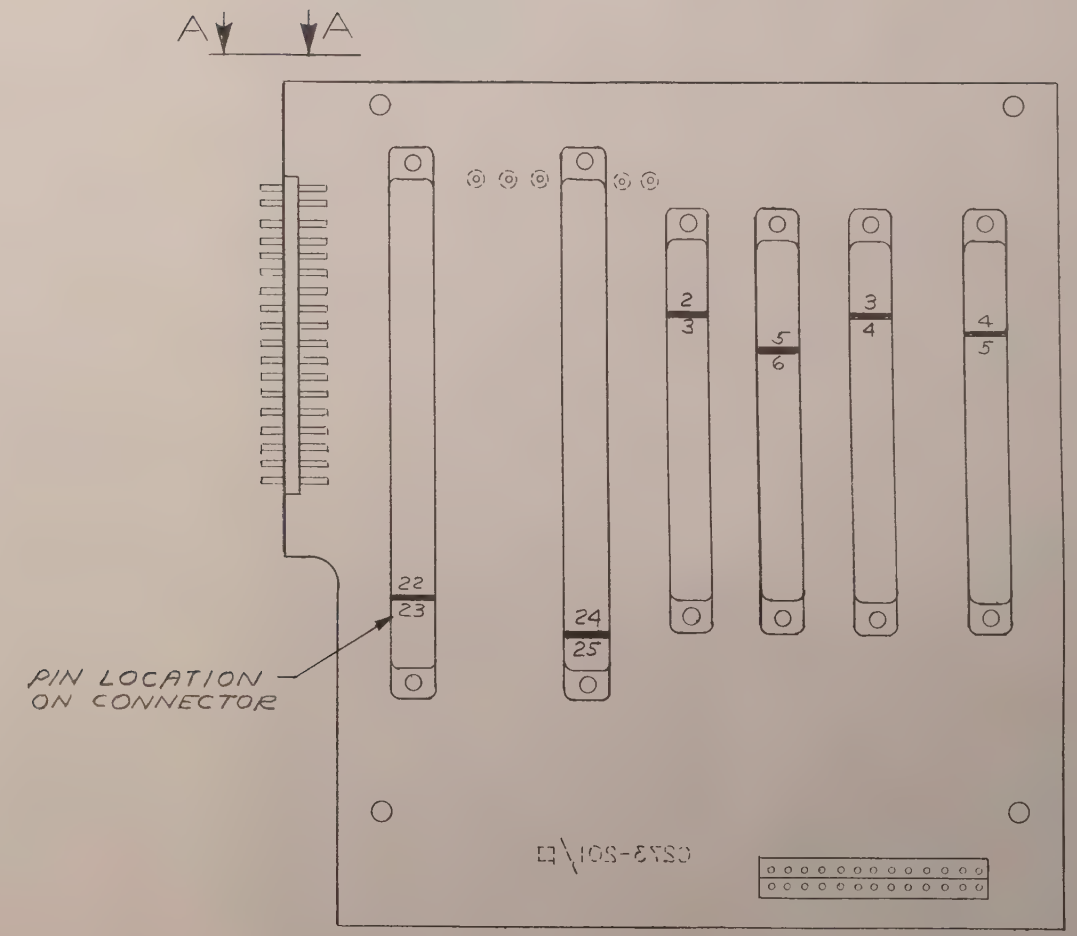
Display Module (A1) Schematic
D273-100/C



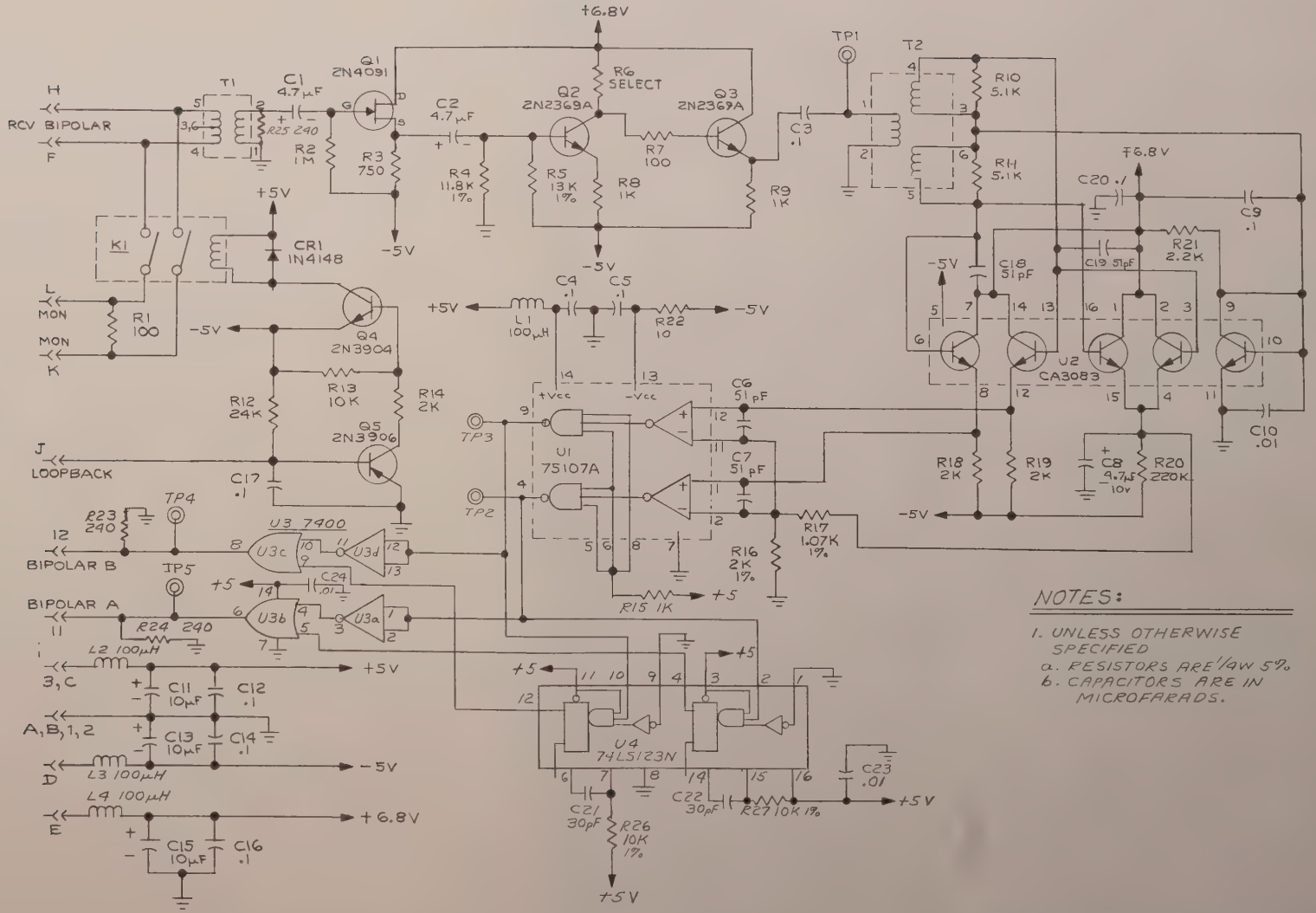
Display Module (A1) Assembly
C273-200/D



Interconnect Module (A2) Schematic
E273-101/D



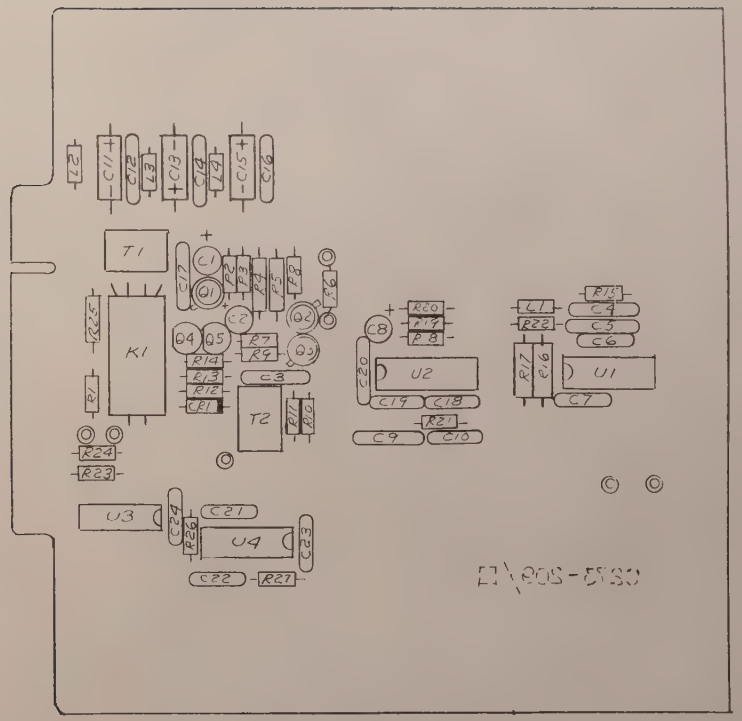
Interconnect Module (A2) Assembly
C273-201/A



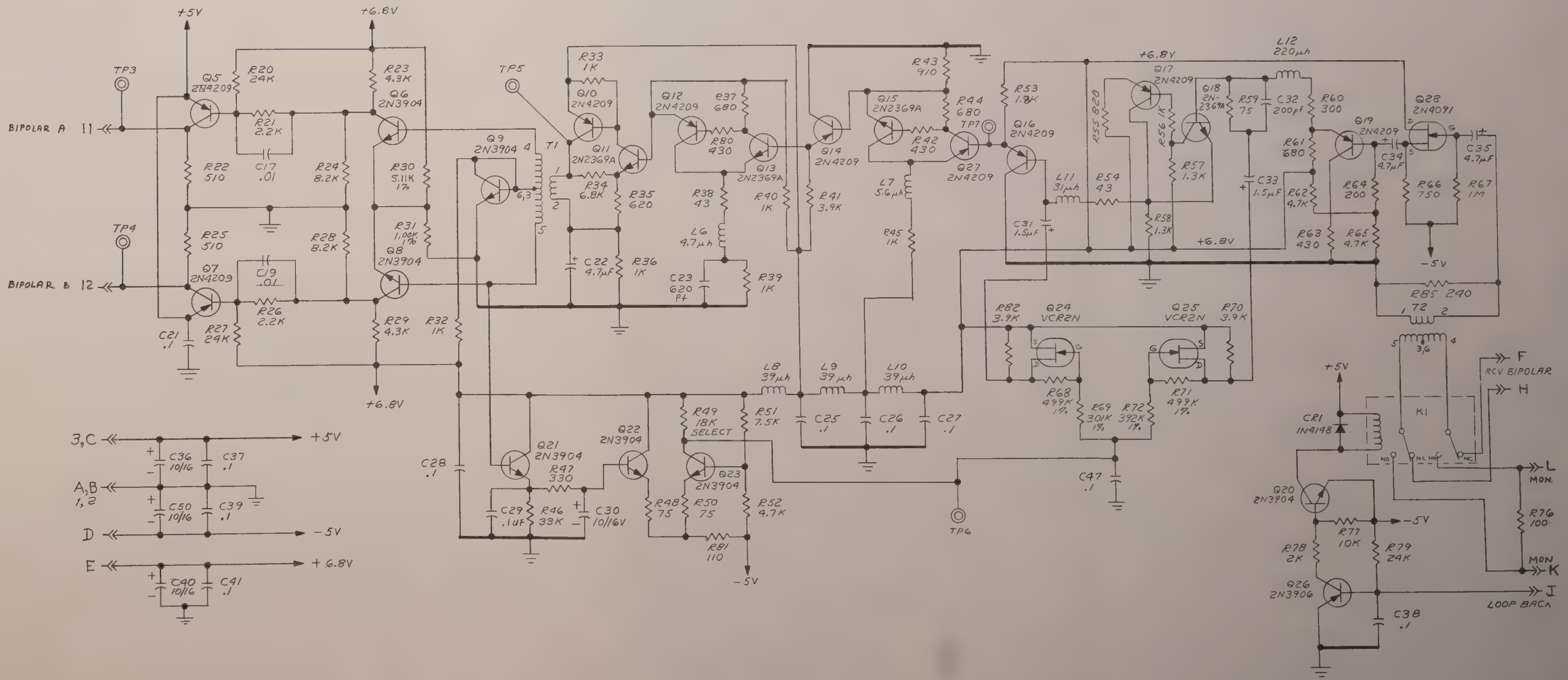
NOTES:

1. UNLESS OTHERWISE SPECIFIED
   a. RESISTORS ARE 1/4W 5%.
   b. CAPACITORS ARE IN MICROFARADS.

Receiver Module (A3) Variable Threshold Schematic
C273-109/B

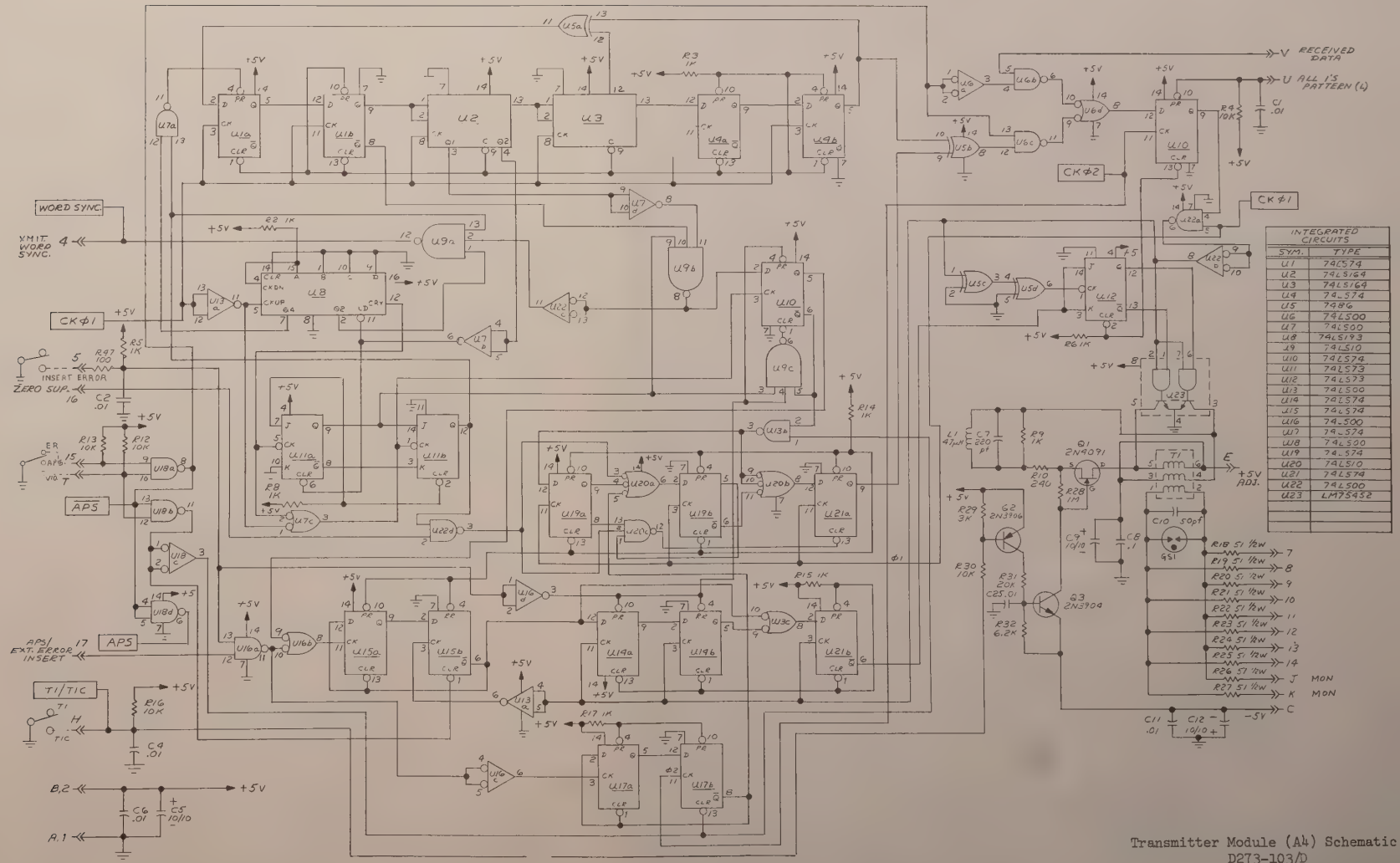


Receiver Module (A3) Variable Threshold Assembly
J273-209/C



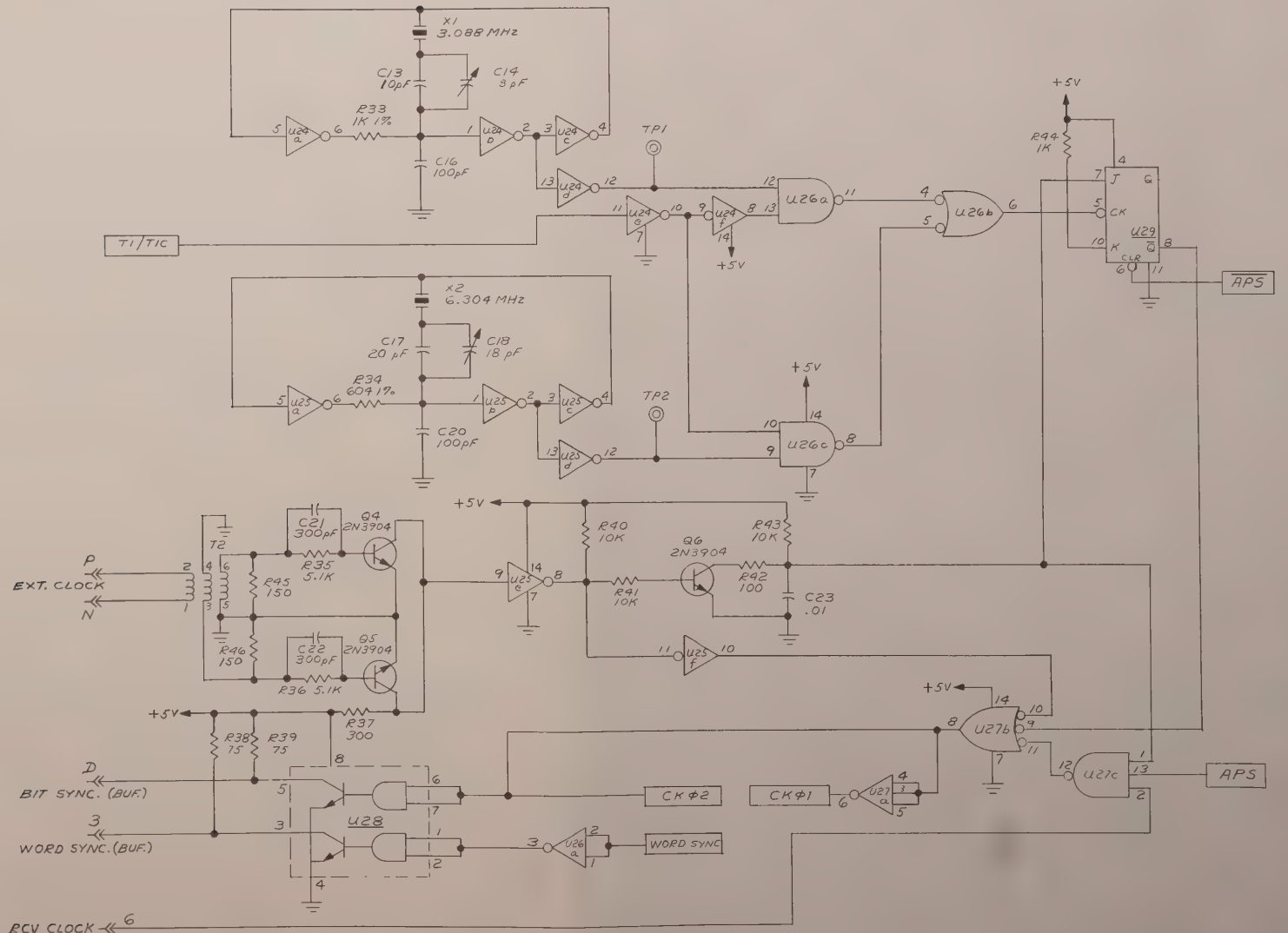
Receiver Module, Option (A3) ALBO Schematic
D273-102/F

Receiver Module, Option (A3) ALBO Assembly
8273-302 E



INTEGRATED CIRCUITS	
SYM.	TYPE
U1	74LS74
U2	74LS164
U3	74LS164
U4	74_574
U5	7486
U6	74LS00
U7	74LS00
U8	74LS193
U9	74LS10
U10	74LS74
U11	74LS73
U12	74LS73
U13	74LS00
U14	74LS74
U15	74_574
U16	74_500
U17	74_574
U18	74LS20
U19	74_574
U20	74LS10
U21	74LS74
U22	74LS00
U23	LM75452

Transmitter Module (A4) Schematic
D273-103/D
(Sheet 1 of 2)

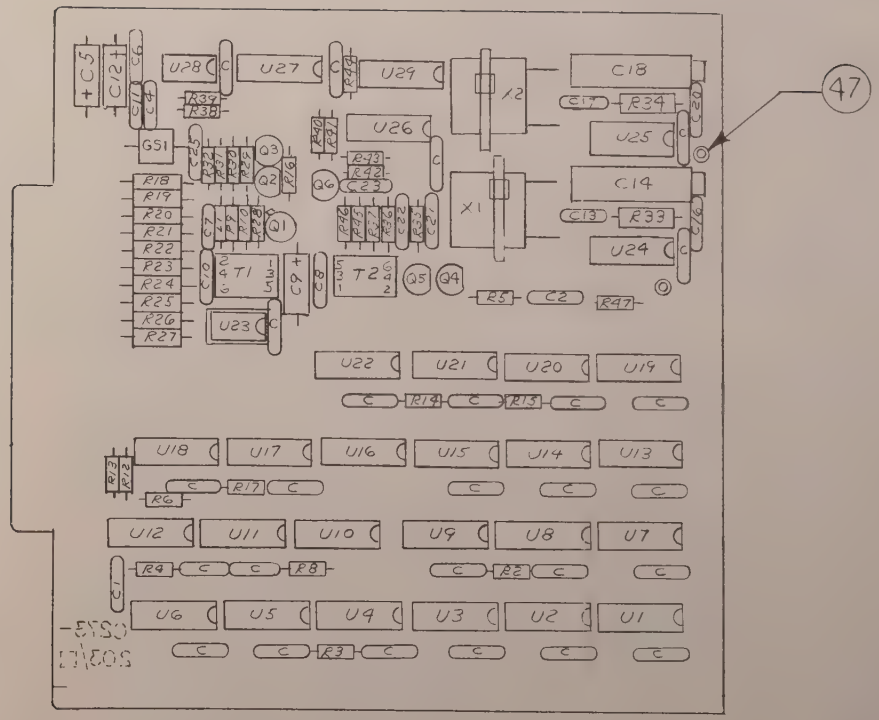


INTEGRATED CIRCUITS	
SYM.	TYPE
U24	7404N
U25	74S04
U26	74LS00
U27	74CS10
U28	75452
U29	74LS73

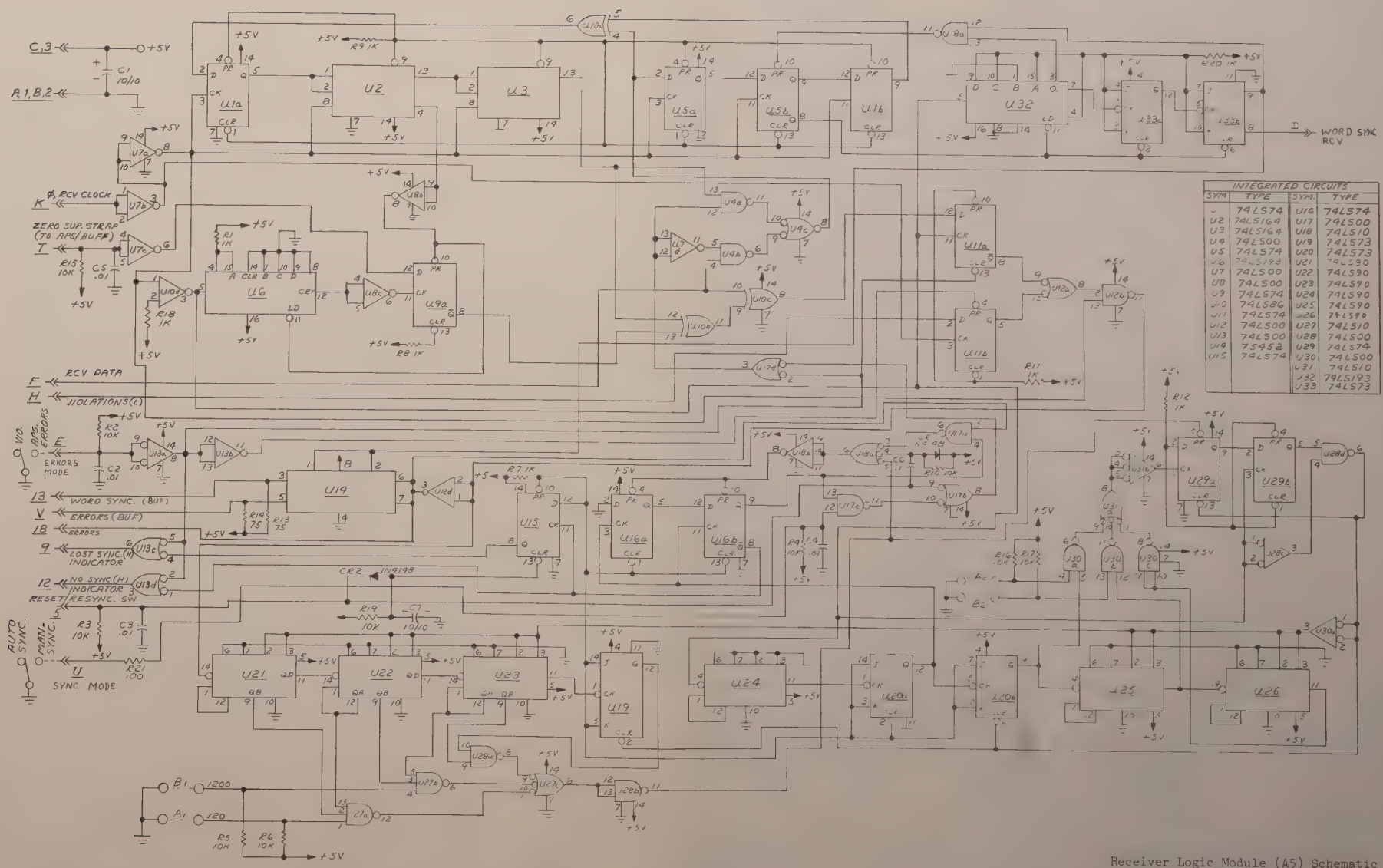
NOTES:

1. UNLESS OTHERWISE SPECIFIED: RESISTORS ARE IN OHMS, 1/4 WATT, 5%. CAPACITORS ARE IN MICROFARADS.

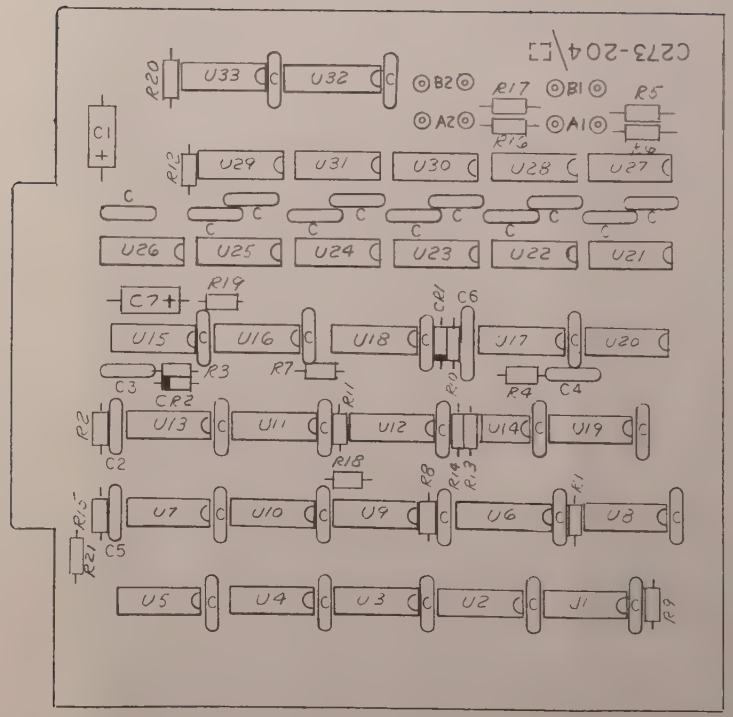
Transmitter Module (A4) Schematic
D273-103/D
(Sheet 2 of 2)



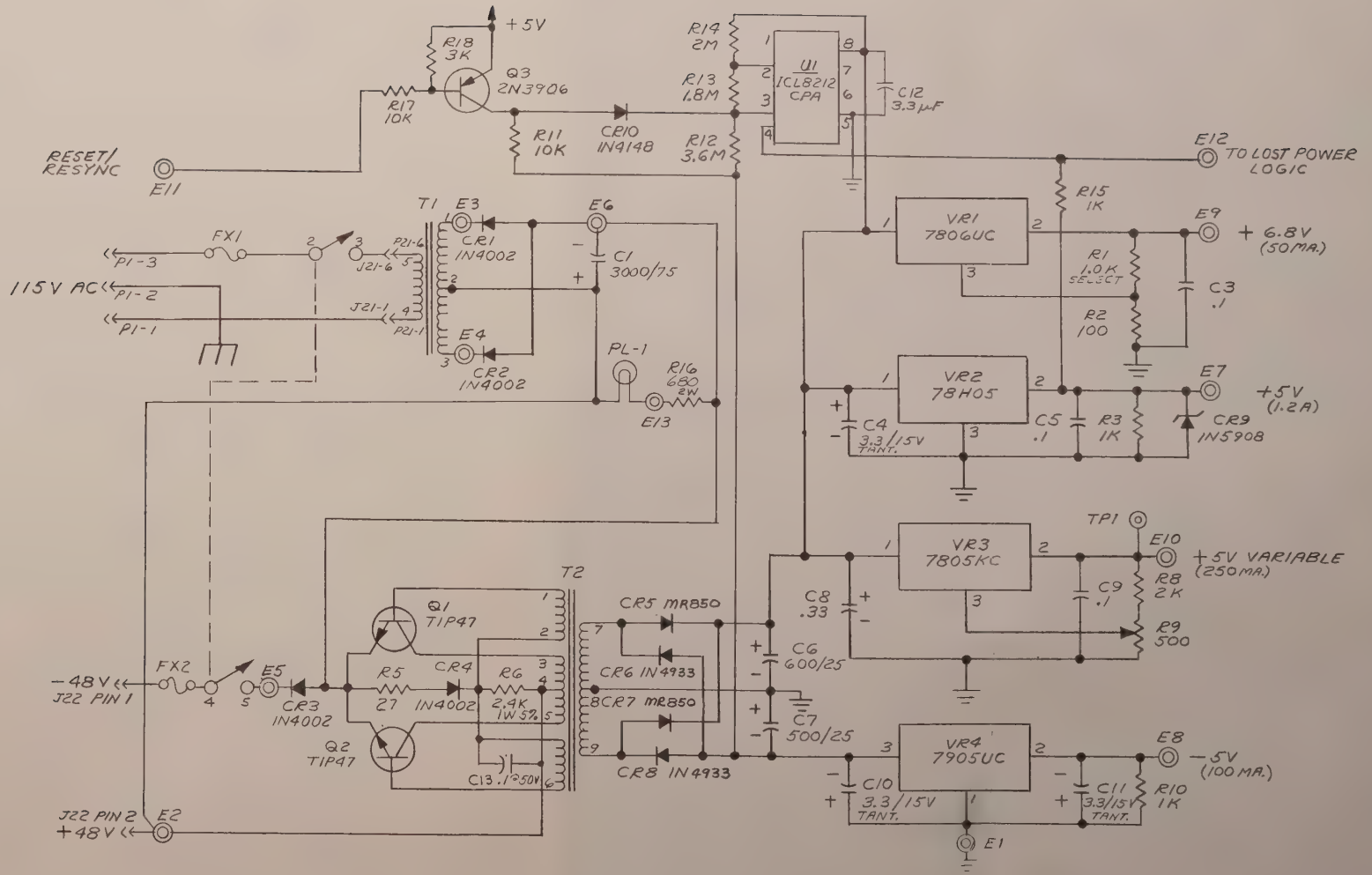
Transmitter Module (A4) Assembly
CD73-203/D



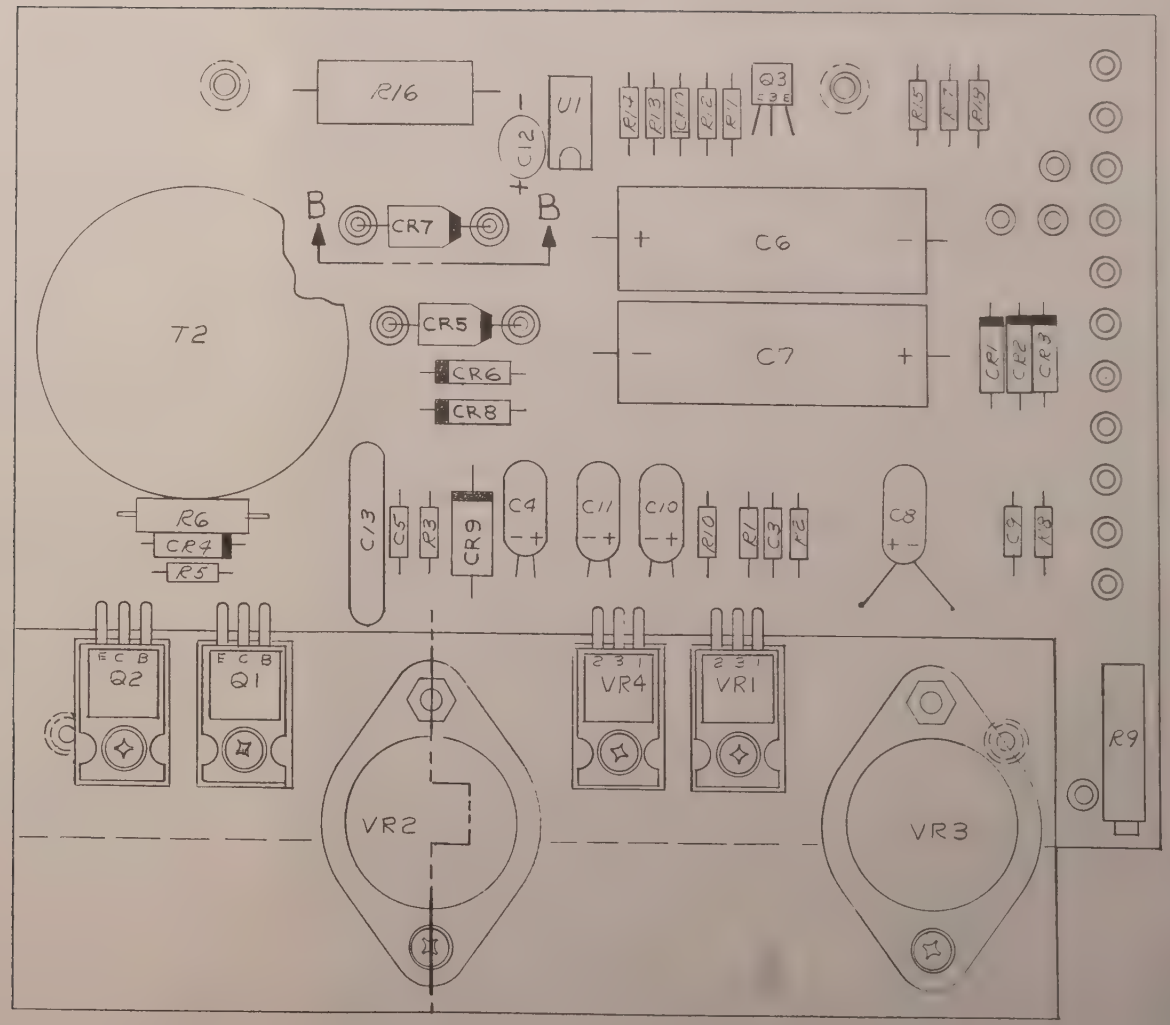
Receiver Logic Module (A5) Schematic
D273-104/B



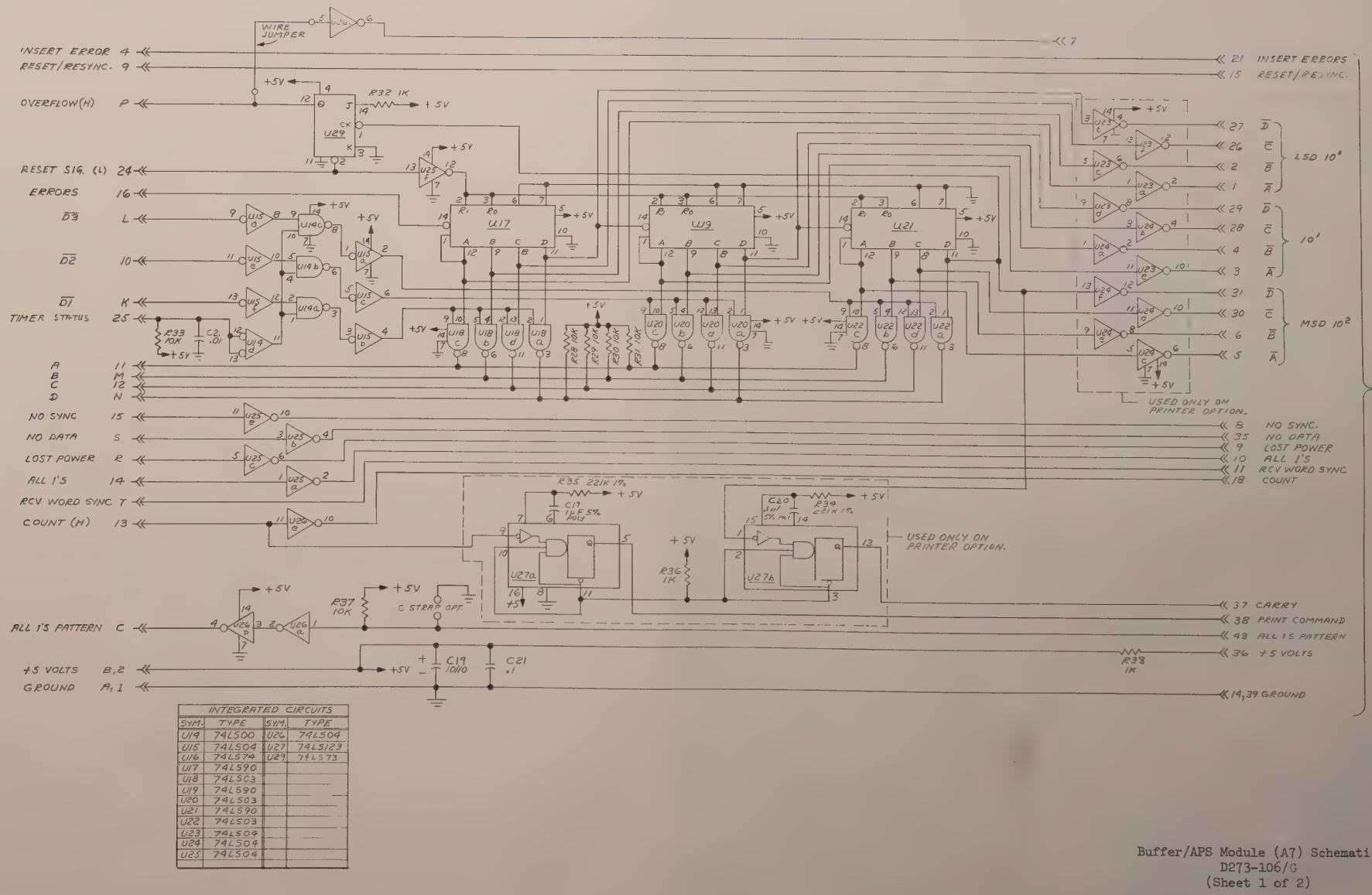
Receiver Logic Module (A5) Assembly
CC7-204/D



Power Supply Module (A6) Schematic
C273-105/F

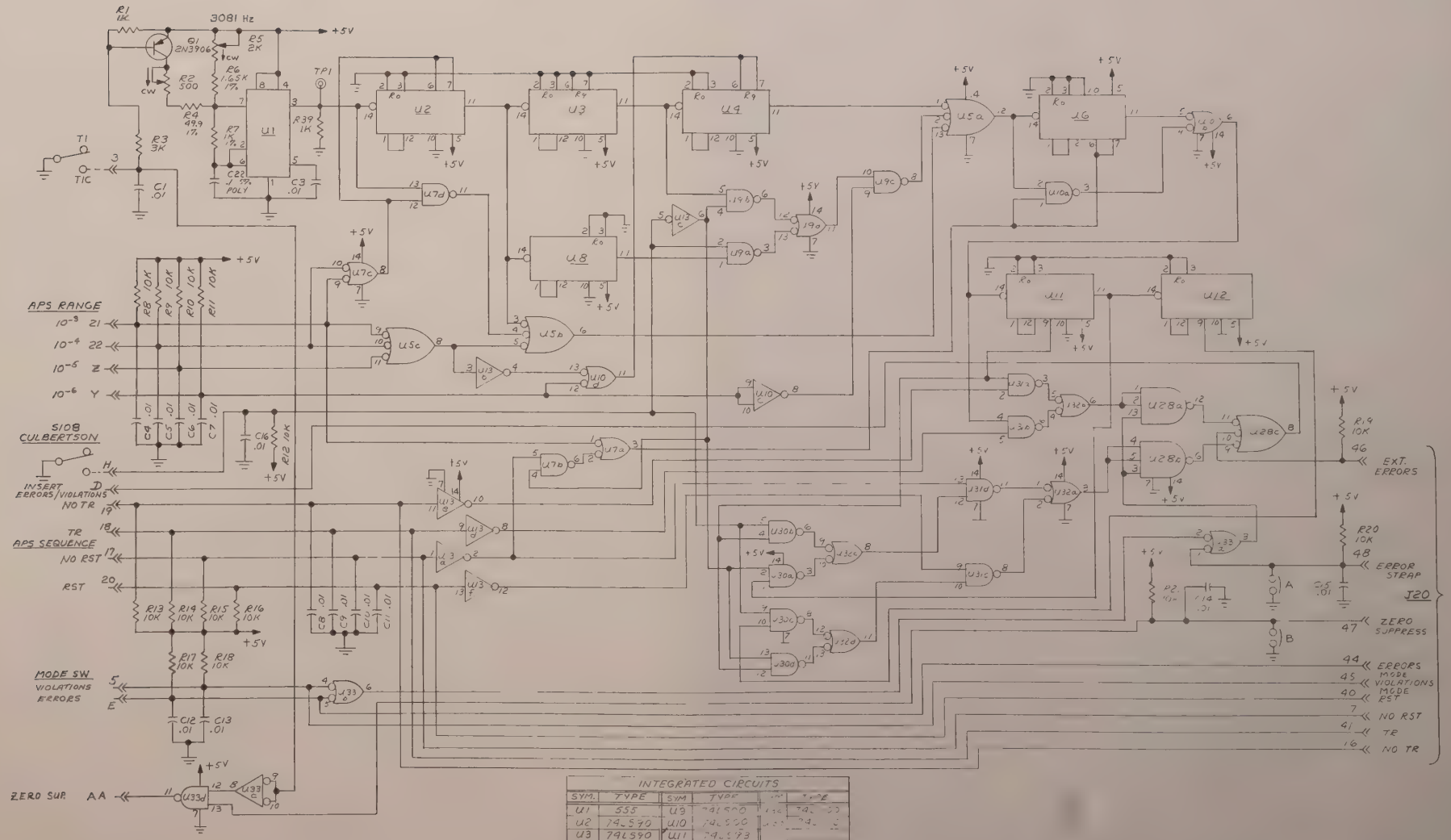


Power Supply Module (A6) Assembly
D078-2015/C



INTEGRATED CIRCUITS			
SYM.	TYPE	SYM.	TYPE
U19	74LS00	U26	74LS04
U15	74LS04	U27	74LS123
U16	74LS74	U29	74LS73
U17	74LS90		
U18	74LS63		
U19	74LS90		
U20	74LS03		
U21	74LS90		
U22	74LS03		
U23	74LS04		
U24	74LS04		
U25	74LS04		

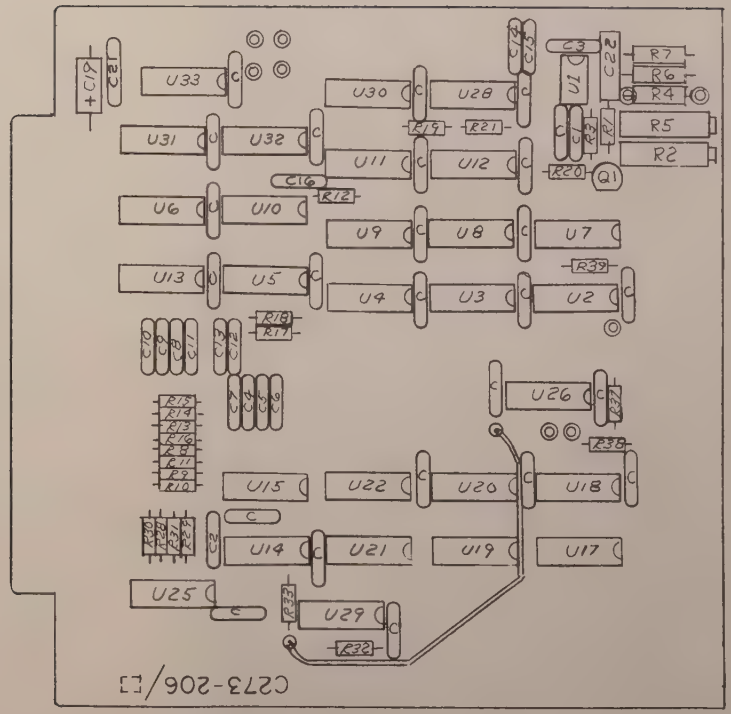
Buffer/APS Module (A7) Schematic
D273-106/G
(Sheet 1 of 2)



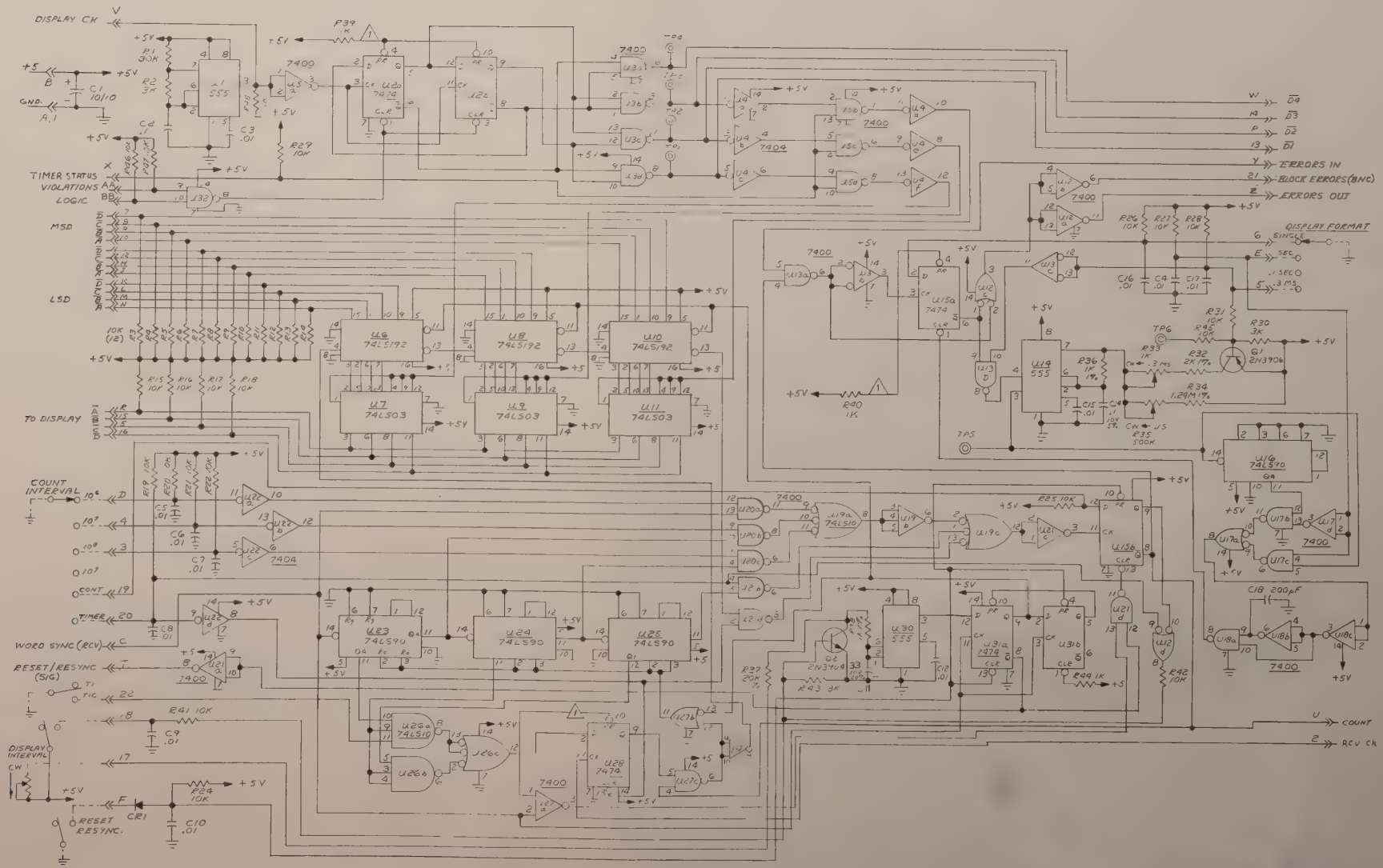
INTEGRATED CIRCUITS

SYM.	TYPE	SYM	TYPE
U1	555	U9	74LS00
U2	74LS70	U10	74LS20
U3	74LS90	U11	74LS73
U4	74LS90	U12	74LS93
U5	74LS10	U13	74LS19
U6	74LS70	U28	74LS10
U7	74LS00	U30	74LS00
U8	74LS93	U31	74LS00

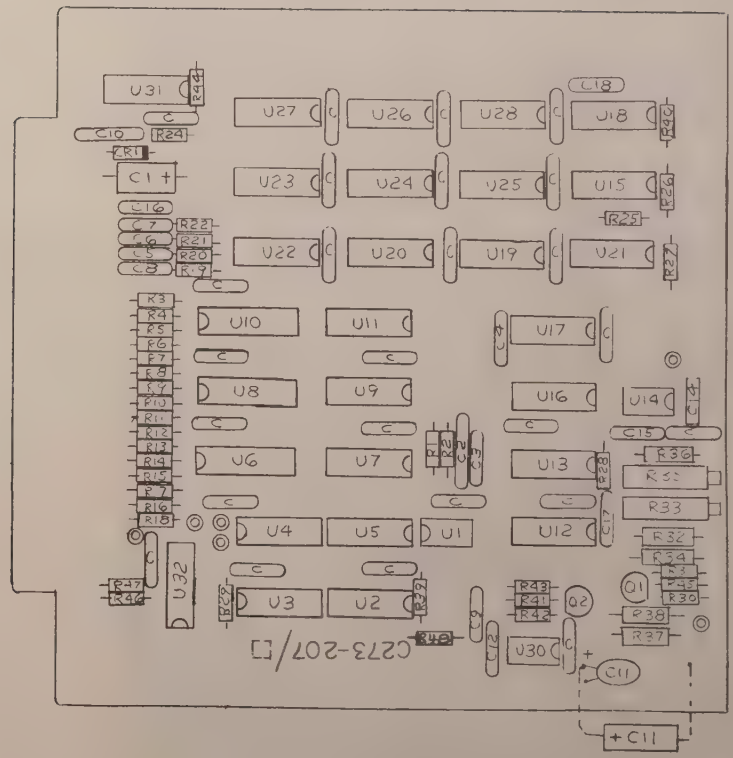
Buffer/APS Module (A7) Schematic
D273-106/G
(Sheet 2 of 2)



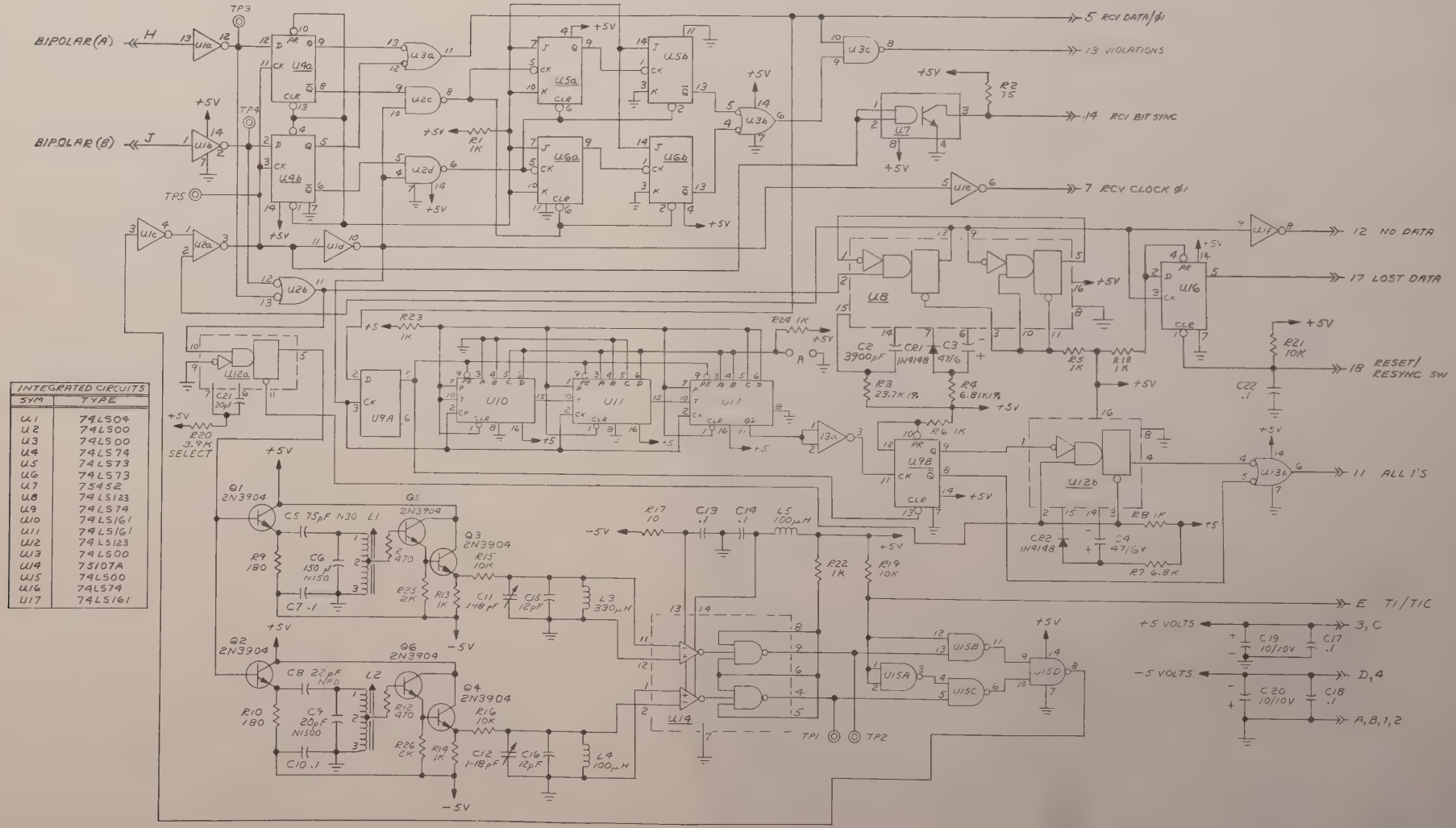
Buffer/APS Module (A7) Assembly
C273-206/F



Display Logic (A8) Schematic
D273-107/E



Display Logic (A8) Assembly
C.T.-371

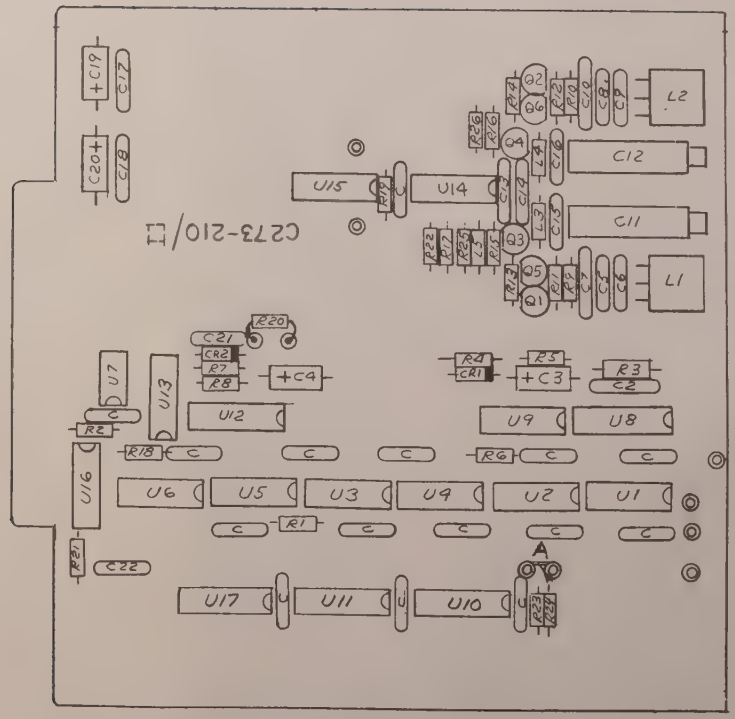


INTEGRATED CIRCUITS	
SYM	TYPE
U1	74LS04
U2	74LS00
U3	74LS00
U4	74LS74
U5	74LS73
U6	74LS73
U7	75452
U8	74LS123
U9	74LS74
U10	74LS161
U11	74LS161
U12	74LS123
U13	74LS00
U14	75107A
U15	74LS00
U16	74LS74
U17	74LS161

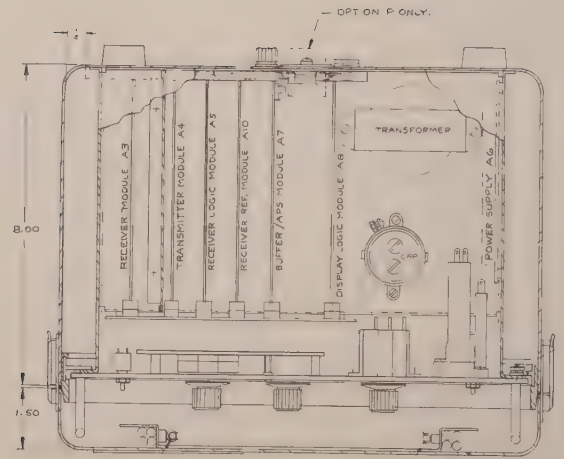
NOTES:

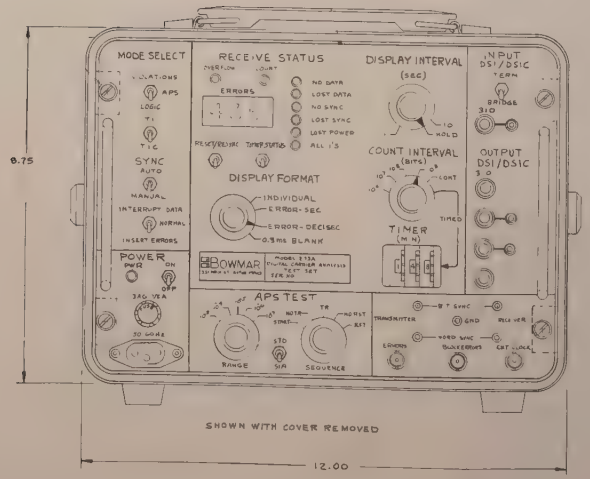
1. UNLESS OTHERWISE SPECIFIED:
   a. RESISTORS ARE IN OHMS, 1/4 WATT 5%.
   b. CAPACITORS ARE IN MICROFARADS.

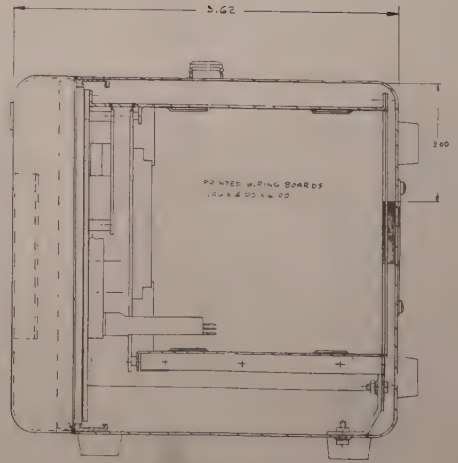
Receiver Reference Module (A10) Schematic
D273-110/F



Receiver Reference Module (A10) Assembly
C273-210/L







Digitial Carrier Analysis Test Set Assembly
E273-001/C

PARTS AND MANUFACTURERS

Items listed herein are electrical and circuit components. They are grouped under the title of associated modules. Each part is itemized by REF. DES. (Reference Designation) and described according to title, values, manufacturer, and manufacturer's identification number. Exception to providing manufacturer identification is taken where the part is standardized RETMA. Any manufacturer registered for RETMA parts will be acceptable.

REF. DES.	COMPONENT DESCRIPTION	COMPONENT MANUFACTURER	PART NO.
DISPLAY MODULE (A1)			
U1-U2	Inverter	T.I.	74LS04N
U3	Decoder 7-Seg. (BCD)	T.I.	74LS47N
U4	D-Type Flip Flop	T.I.	74LS74N
U5, U6, U7	LED 7-Seg. Display	H.P.	5082-7650
DS1-DS8	LED Indicator	H.P.	5082-4650
Q1-Q4	Transistor		2N4403
R2, R4, R6, R22	Resistor 330, 1/4W, 5%		RLR07C331J
R1, R3, R5, R23	Resistor 1K, 1/4W, 5%		RLR07C102J
R7-R13	Resistor 68, 1/4W, 5%		RLR07C680J
R14-R21	Resistor 270, 1/4W, 5%		RLR07C271J
S1-S2	PC Mount None-On-(On)	C&K	7109SPV30CQE
C1	Capacitor .luf, 20V Disc.	Centralab	UK-16-104
C2	Capacitor 10uf, 16V, El.	Sprague	TE-1155E
Q5	Transistor		2N3904
R24	Resistor, 10K, 1/4W, 5%		RLR07C103J
R25	Resistor 100 ohm, 1/4W, 5%		RLR07C101J
R26	Resistor 10 ohm, 1/4W, 5%		RLR07C100J
RECEIVER THRESHOLD (A3)			
R1, R7	Resistor 100 ohm, 1/4W, 5%		RLR07C101J
R2	Resistor 1M, 1/4W, 5%		RLR07C105J
R3	Resistor 750 ohm, 1/4W, 5%		RLR07C751J
R4	Resistor 11.8K, 1/8W, 1%		RN60C1182F
R5	Resistor 13K, 1/8W, 1%		RN60C1302F
R6	Resistor, 2K, 1/8W, 1%		RN60C202F
R8, R9, R15	Resistor 1K, 1/4W, 5%		RLR07C102J
R10, R11	Resistor 5.1K, 1/4W, 5%		RLR07C512J
R12	Resistor 24K, 1/4W, 5%		RLR07C243J
R13	Resistor 10K, 1/4W, 5%		RLR07C103J
R14, R18, R19	Resistor 2K, 1/4W, 5%		RLR07C202J
R16	Resistor 2K, 1/8W, 1%		RN60C2001F
R20	Resistor 220K, 1/4W, 5%		RLR07C224J

REF. DES.	COMPONENT DESCRIPTION	COMPONENT MANUFACTURER	PART NO.
RECEIVER THRESHOLD (A3) (con't)			
R21	Resistor 2.2K, 1/4W, 5%		RLR07C222J
R22	Resistor 10 ohm, 1/4W, 5%		RLR07C100J
R23, R24, R25	Resistor 240, 1/4W, 5%		RLR07C241J
R17	Resistor 1.07K, 1/8W, 1%		RN60C1071F
C1, C2, C8	Capacitor Tant. 4.7uf, 10V	Sprague	19D475X901-0HA1
C3,C4,C5,C9,C12,C14, C16,C17,C20	Capacitor .1uf	Centralab	UK-16-104
C6,C7,C18,C19	Capacitor 51pf, 5%	CDE	CD10ED510J03
C10, 23, 24	Capacitor .01uf	Centralab	UK-16-103
C11,C13,C15	Capacitor Tant. 10uf, 16V	Sprague	TE-1155E
U1	Integrated Circuit	T.I.	SN75107A
U2	Integrated Circuit	RCA	CA3083
Q1	Transistor		2N4091
Q2, Q3	Transistor		2N2369A
Q4	Transistor		2N3904
Q5	Transistor		2N3906
CR1	Diode		1N4148
T1, T2	Transformer	Pulse Eng.	PE5763
K1	Relay	Coto-Coil	1235-12-0101
L1, L2, L3, L4	Inductor 100uh	Lenox Fugle	NR-100, LF-100
C21, 22	Capacitor, S.M. 30 pf		CM04
U4	Integrated Circuit		74LS123N

REF. DES.	COMPONENT DESCRIPTION	COMPONENT MANUFACTURER	PART NO.
RECEIVER MODULE (A3) (ALBO)			
Q28	Transistor FET		2N4091
Q19, 17, 16, 5, 7, 27, 14, 12, 10	Transistor PNP		2N4209
Q18, 15, 13, 11	Transistor NPN		2N2369A
Q6, 8, 9, 20, 21, 22, 23	Transistor NPN		2N3904
Q26	Transistor PNP		2N3906
Q24, 25	Transistor FET		VCR2N
R67	Resistor 1M, 5%, 1/4W		RLR07C105J
R66	Resistor 750, 5%, 1/4W		RLR07C751J
R64	Resistor 200, 5%, 1/4W		RLR07C201J
R65, 62, 52	Resistor 4.7K, 5%, 1/4W		RLR07C472J
R35	Resistor 620, 5%, 1/4W		RLR07C621J
R60	Resistor 300, 5% 1/4W		RLR07C301J
R59, 48, 50	Resistor 75, 5%, 1/4W		RLR07C750J
R57, 58	Resistor 1.3K, 5%, 1/4W		RLR07C132J
R45, 39, 32, 33, 56, 40, 36	Resistor 1K, 5%, 1/4W		RLR07C102J
R55	Resistor 820, 5%, 1/4W		RLR07C821J
R54, 38	Resistor 43, 5%, 1/4W		RLR07C430J
R53	Resistor 1.8K, 5%, 1/4W		RLR07C182J
R44, 37, 61	Resistor 680, 5%, 1/4W		RLR07C681J
R43	Resistor 910 5%, 1/4W		RLR07C911J
R42, 80, 63	Resistor 430, 5%, 1/4W		RLR07C431J
R41, 82, 70	Resistor 3.9K, 5%, 1/4W		RLR07C392J
R78	Resistor 2K, 5%, 1/4W		RLR07C202J
R23, 29	Resistor 4.3K, 5%, 1/4W		RLR07C432J
R76	Resistor 100, 5%, 1/4W		RLR07C101J
R24, 28	Resistor 8.2K, 5%, 1/4W		RLR07C822J
R26, 21	Resistor 2.2K, 5%, 1/4W		RLR07C222J
R22, 25	Resistor 510, 5%, 1/4W		RLR07C511J
R20, 27, 79	Resistor 24K, 5%, 1/4W		RLR07C243J
R47	Resistor 330, 5%, 1/4W		RLR07C331J
R46	Resistor 33K, 5%, 1/4W		RLR07C333J
R81	Resistor 110, 5%, 1/4W		RLR07C111J
R49	Resistor 8.2K, 5%, 1/4W Select		RLR07C822J
R51	Resistor 7.5K, 5%, 1/4W		RLR07C752J
R77	Resistor 10K, 5%, 1/4W		RLR07C103J
R34	Resistor 6.8K, 5%, 1/4W		RLR07C682J
R30	Resistor 5.11K, 1%, 1/8W		RN60C5111F

REF. DES.	COMPONENT DESCRIPTION	COMPONENT MANUFACTURER	PART NO.
RECEIVER MODULE (A3) (ALBO) (con't)			
R31	Resistor 1.00K, 1%, 1/8W		RN60C1001F
R68, 71	Resistor 499K, 1%, 1/8W		RN60C4993F
R69	Resistor 301K, 1%, 1/8W		RN60C3013F
R72	Resistor 392K, 1%, 1/8W		RN60C3923F
C35, 34, 22	Capacitor 4.7uf, Tant.	Sprague	196D475X9010HA1
C33, 31	Capacitor 1.5uf	Sprague	196D155X9025HA1
C32	Capacitor 200pf, Sil. Mica		CM04FD201J03
C25-28, 21, 47, 37, 38, 39, 41, 29	Capacitor .1uf, 20V, Disc.	Centralab	UK-16-104
C23	Capacitor 620pf Sil. Mica		CM06FD621J03
C36, 50, 40, 30	Capacitor 10uf, 16V, El.	Sprague	TE-1155E
C17, 19	Capacitor, .01mf	Centralab	UK-16-103
L12	Coil 220NH		NR-220, LF-220
L11	Coil 31NH		NR-31, LF-31
L7	Coil 5.6NH		NR-5.6, LF-5.6
L10, 9, 8	Coil 39NH		NR-39, LF-39
L6	Coil 4.7NH		NR-4.7, LF-4.7
T1, T2	Transformer Pulse 1:1:1	Pulse Engineering	PE5763
K1	Relay	Coto-Coil	1235-12-0101
CR1	Diode		1N4148
TP3-7	Terminals	Cambion	2027-2
R85	Resistor, 240 ohm, 1/4W, 5%		RLR07C241J
TRANSMITTER MODULE (A4)			
U1, 4, 10, 14, 15, 17, 19, 21	D Type Flip Flop	T.I.	74LS74N
U2, 3	8 Bit Shift Register	T.I.	74LS164N
U5	Exclusive OR	T.I.	74LS86N
U6, 7, 13, 16, 18, 22, 26	Quad 2 Input NAND	T.I.	74LS00N
U8	4 Bit Up/Down Counter	T.I.	74LS193N
U9, 20, 27	Triple 3 Input NAND	T.I.	74LS10N
U12, 29, 11	JK Flip Flop	T.I.	74LS73N
U23, 28	Line Driver	T.I.	LM75452
U25, 24	Hex Inverter	T.I.	74LS07N
Q1	Fet		2N4091
Q2	PNP Transistor		2N3906
Q3, 4, 5, 6	NPN Transistor		2N3904

REF. DES.	COMPONENT DESCRIPTION	COMPONENT MANUFACTURER	PART NO.
TRANSMITTER MODULE (A4) (con't)			
X1	3.088 MC Xtal Crystal	Bowmar	B6440
X2	6.304 MC Xtal Crystal	Bowmar	B6441
R2, 3, 5, 6, 8, 9, 14, 15, 17, 44	Resistor 1K, 5%, 1/4W		RLR07C102J
R4, 12, 13, 16, 30, 40, 41, 43	Resistor 10K, 5%, 1/4W		RLR07C103J
R10	Resistor 240, 5%, 1/4W		RLR07C241J
R18-27	Resistor 51, 5%, 1/2W		RLR20C510J
R28	Resistor 1M, 5%, 1/4W		RLR07C105J
R29	Resistor 3K, 5%, 1/4W		RLR07C302J
R31	Resistor 20K, 5%, 1/4W		RLR07C203J
R32	Resistor 6.2K, 5%, 1/4W		RLR07C622J
R33	Resistor 1K, 1%, 1/8W		RN60C1001F
R35, 36	Resistor 5.1K, 5%, 1/4W		RLR07C512J
R37	Resistor 300, 5%, 1/4W		RLR07C301J
R42, 47	Resistor 100, 5%, 1/4W		RLR07C101J
R45, 46	Resistor 150, 5%, 1/4W		RLR07C151J
C1, 2, 4, 6, 11, 23, 25	Capacitor .01uf, Disc.	Centralab	UK-16-103
C5, 9, 12	Capacitor 10uf, 16V, Tant.	Sprague	TE-1155E
C7	Capacitor, 220pf, Silver Mica	CDE	CD10FD221J03
C8	Capacitor .1uf	Centralab	UK-16-104
C10	Capacitor 50pf, Silver Mica	CDE	CD10ED500J03
C13, 17	Capacitor 10pf, 5%, N1500	RMC	CG10-NPO 5%
C14, 18	Capacitor 1-18pf Adj.	Sprague-Goodman	GGC-18000
C16, 20	Capacitor 100pf, Silver Mica	CDE	CD10FD101J03
C21, 22	Capacitor 300pf, Silver Mica	CDE	CD10FC301J03
R38, 39	Resistor 75, 5%, 1/4W		RLR07C750J
T1, 2	Pulse Transformer 200uh	Pulse Engineering	PE5763
L1	47uh Coil	Lenox Fugle	LF47
GS1	Trancient Suppressor		CG90L
R34	Resistor, 604, 1/8W, 1%		RN60C6040F
RECEIVER LOGIC (A5)			
U1, 5, 9, 11, 15, 16, 29	D Type Flip Flop	T.I.	74LS74N
U2, 3	Shift Register, 8 Bit	T.I.	74LS164N
U4, 7, 8, 12, 13, 17, 28, 30	Quad NAND	T.I.	74LS00N
U6, 32	Counter Binary Up/Down	T.I.	74LS193N

REF. DES.	COMPONENT DESCRIPTION	COMPONENT MANUFACTURER	PART NO.
RECEIVER LOGIC (A5) (con't)			
U14	Line Driver	T.I.	LM-75452
U18, 27, 31	Triple 3 Input NAND	T.I.	74LS10N
U19, 20, 33	JK Type Flip Flop	T.I.	74LS73N
U21, 22, 23, 24, 25, 26	Decade Counter	T.I.	74LS90N
R1, 7, 8, 9, 11, 12, 18, 20	Resistor 1K, 5%, 1/4W		RLR07C102J
R2, 3, 4, 5, 6, 10, 15, 16, 17, 19	Resistor 10K, 5%, 1/4W		RLR07C103J
CR1, 2	Diode		1N4148
C1, 7	Capacitor 10uf	Sprague	TE-1155E
C2, 3, 4, 5	Capacitor .01uf, Disc.	Centralab	UK-16-103
C6	Capacitor .1uf, Disc.	Centralab	UK-16-104
R14, 13	Resistor 75, 5%, 1/4W		RLR07C750J
U10	Quad EX-OR		74LS86N
R21	Resistor, 100, 1/4W, 5%		RLR07C101J
POWER SUPPLY MODULE (A6)			
VR1	6VDC Reg. with Mica Insulator & Shoulder Washers	Fairchild	UA 7806 UC
VR2	5VDC Reg. with Mica Insulator & Shoulder Washers	Fairchild or Lambda	UA 78H05 SC or LAS 1905
VR3	5VDC Reg. with Mica Insulator & Shoulder Washers	Fairchild	UA 7805 KC
VR4	-5VDC Reg. with Mica Insulator & Shoulder Washers	Fairchild	UA 7905 UC
CR1, 2, 3, 4	Diode		1N4002
CR5, 7	Diode	Motorola	MR850
CR6, 8	Diode	Motorola	1N4933
Q1, 2	Power Transistor with Mica Insulator and Shoulder Washers		TIP 47
Q3	Transistor		2N3906
CR9	Zener Diode		1N5908
CR10	Diode		1N4148
T2	Transformer Converter SCD	Bowmar	C6447
IC1	IC	Intersil	ICL8212CPA
R1	Resistor 1.0K, 5%, 1/4W		RLR07C102J
R2	Resistor 100, 5%, 1/4W		RLR07C101J
R3, 10, 15	Resistor 1K, 5%, 1/4W		RLR07C102J
R5	Resistor 27, 5%, 1/2W		RLR20C270J
R6	Resistor 2.4K, 5%, 1W		RLR32C242J

REF. DES.	COMPONENT DESCRIPTION	COMPONENT MANUFACTURER	PART NO.
POWER SUPPLY MODULE (A6) (con't)			
R8	Resistor 2K, 5%, k/4W		RLR07C202J
R9	Pot. 500 ohm		89WR500 or Equiv.
R11, 17	Resistor 10K, 5%, 1/4W		RLR07C103J
R12	Resistor 3.6M, 5%, 1/4W		RC07GF365J
R13	Resistor 1.8M, 5%, 1/4W		RLR07C185J
R14	Resistor 2M, 5%, 1/4W		RLR07C205J
R16	Resistor 680, 5%, 2W		RL42S681JTX
C3, 5, 9	Capacitor .1uf		UK-16-104
C4, 10, 11, 12	Capacitor 3.3uf/15VDC Tant.		196D335X9015HA1 or equiv.
C8	Capacitor .33uf/35VDC Tant.		196D334X9035HA1
C6	Capacitor 600uf/25VDC		500D607G025FK7
C7	Capacitor 500uf/25VDC		500D507G025FH7
E1-12	Terminals	Cambion	2027-2
R18	Resistor 3K, 5%, 1/4W		RLR07C302J
C13	Capacitor .1uf @50V Disc.	Centralab	CK-104
BUFFER/APS MODULE			
U2, 3, 4, 6, 21, 17 19	Decade Counter	T.I.	SN74LS90N
U5, 28	Triple 3 In. NAND	T.I.	SN74LS10N
U7, 9, 10, 30, 31, 14, 32, 33	Quad 2 In. NAND	T.I.	SN74LS00N
U11, 12, 8	Bin Counter	T.I.	SN74LS93N
U13, 15, 25, 26	Hex Inverter	T.I.	SN74LS04N
U29	Dual JK-FF	T.I.	SN74LS73N
U1	Timer	Signetics	NE555N
C21	Capacitor .1mf, Disc.	Centralab	UK-16-104
C1-16	Capacitor .01mf, Disc.	Centralab	UK-16-103
C19	Capacitor 10mf, 16V EL	Sprague	TE-1155E
C22	Capacitor 0.1mf, 5% Poly.	Siemens	B32 561-0.1/5/250
R28-31, 33, 8-21, 37	Resistor 10K, 5%, 1/4W		RLR07C103J
R32, 38, 1, 39	Resistor 1K, 5%, 1/4W		RLR07C102J
R3	Resistor 3K, 5%, 1/4W		RLR07C302J
R4	Resistor, 1.43K, 1%, 1/8W		RN60C1431F
R6	Resistor, 2.80K, 1%, 1/8W		RN60C2801F

REF. DES.	COMPONENT DESCRIPTION	COMPONENT MANUFACTURER	PART NO.
BUFFER/APS MODULE (con't)			
R7	Resistor 499K, 1%, 1/8W		RN60C4990F
R2	Pot. 500 ohm	Bourns	89W500
R5	Pot. 2K	Bourns	89W2K
Q1	Tran. PNP		2N3906
U18, 20, 22	Quad. Input NAND O.C.	T.I.	SN74LS03J
DISPLAY LOGIC (A8)			
U1, 14, 30	Timer	Signetics	NE555
U2, 15, 28, 31	D Type Flip Flop	T.I.	74LS74
U3, 5, 12, 13, 17, 20, 21, 27, 32, 18	Quad 2 Input NAND	T.I.	74LS00
U4, 22	Hex Inverter	T.I.	74LS04
U6, 8, 10	Counter Decade Up/Down	T.I.	74LS192
U7, 9, 11	Quad 2 Input NAND O/C	T.I.	74LS03
U16, 23, 24, 25	Counter BCD	T.I.	74LS90
U19, 26	Triple 3 Input NAND	T.I.	74LS10
Q1	Transistor PNP	Motorola/ITT	2N3906
Q2	Transistor NPN	Motorola/ITT	2N3904
R1	Resistor 30K, 5%, 1/4W		RLR07C303J
R2, 30, 43	Resistor 3K, 5%, 1/4W		RLR07C302J
R3-22, 24-29, 41, 42, 45, 46, 47, 31	Resistor 10K, 5%, 1/4W		RLR07C103J
R32	Resistor 1.5K, 1%		RN60C1501F
R33	Resistor 1K, Var.	Bourns	89WR1K
R34	Resistor 1.24M, 1%		RN60C1244F
R35	Resistor 500K, Var.	Bourns	89WR500K
R36, 38	Resistor 1K, 1%		RN60C1001F
R37	Resistor 20K, 1%		RN60C2002F
R44, 40, 39, 48	Resistor 1K, 5%, L/4W		RLR07C102J
C1	Capacitor 10uf, 16V, EL	Sprague	TE-1155E
C2, C10	Capacitor .luf, Disc.	Centralab	UK-16-104
C3, 15, 12, 5, 6, 7, 8, 9, 16, 17, 4, 10	Capacitor .01uf Disc.	Centralab	UK-16-103
C11	Capacitor 33 uf, 10V Tant. 20%	Sprague	196D336X9010KA1
C14	Capacitor .luf, 5%, Polycarb	Siemens	B32561-0.1/5/250
CR1	Diode Sig.		1N4148
C18	Capacitor 200pf, Silver Mica		CM04FD201J03

REF. DES.	COMPONENT DESCRIPTION	COMPONENT MANUFACTURER	PART NO.
RECEIVER REFERENCE MODULE (A10)			
U4, 9, 16	Dual D-Type Flip Flop		74LS74N
U5, 6	Dual JK-Type Flip-Flop		74LS73N
U15, 13, 2, 3	Quad 4 Input NAND		74LS00N
U10, 11, 17	BCD Counter		74LS161AN
U14	Line Receiver		75107AN
U7	Line Driver		75452
U12, 8	Dual One Shot		74LS123N
U1	Hex Inverter		74LS04N
R9, 10	Resistor 180, 5%, 1/4W		RLR07C181J
R15, 16, 19, 21	Resistor 10K, 5%, 1/4W		RLR07C103J
R11, 12	Resistor 47, 5%, 1/4W		RLR07C471J
R14, 13, 8, 6, 5, 1, 18, 22, 23, 24	Resistor 1K, 5%, 1/4W		RLR07C102J
R17	Resistor 10, 5%, 1/4W		RLR07C100J
R7	Resistor 6.8K, 5%, 1/4W		RLR07C682J
R20	Resistor 7.5K, 5%, 1/4W		RLR07C752J
R2	Resistor 75, 5%, 1/4W		RLR07C750J
R3	Resistor 23.7K, 1%, 1/4W		RN60C2372F
R4	Resistor 6.81K, 1%, 1/4W		RN60C6811F
C6	Capacitor 150pf	RMC	CM150N150 5%
C5	Capacitor 75pf	RMC	CG75N30 5%
C21	Capacitor 20pf, Silver Mica	Sprague	CM04ED200J03
C10, 7, 13, 14, 17, 18, 22	Capacitor .1 20V, Disc.	Centralab	UK-16-104
C2	Capacitor 3900pf, Silver Mica	Sprague	CM06FD392J03
C3, 4	Capacitor 47uf, 6V, Tant. 10%	Sprague	150D476X0006B2
C19,20	Capacitor 10uf, 16V, EL	Sprague	TE-1155E
C15	Capacitor 12pf, Silver Mica	Sprague	CM04CD120J03
C11, 12	Capacitor 1-18pf, Glass.	Sprague Goodman	GGC-18000
Places Marked "C"	Capacitor .01 @16V EL	Centralab	UK-16-103
CR1, CR2	Diode, Sig.		1N4148
L4, 5	Coil 100uh	Lenox-Fugle	NR-100/LF-100
L3	Coil 330uh	Lenox-Fugle	NR-330/LF-330
L1, L2	Coil 49uh Adj.	Aladdin	B6346
Q1-6	Transistor NPN		2N3904
TP1-8	Terminals	Cambion	2027-2
R25, 26	Resistor, 2K, 1/4W, 5%		RLR07C202J
C8	Capacitor, 22pf	RMC	CG22NPO 5%
G9	Capacitor, 20pf	RMC	CG20N1500 5%

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